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Water Resources Data and Preliminary Trend Analysis for the Blue Creek Watershed Project Pike County, Illinois. Phase I

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WATER RESOURCE DATA AND PRELIMINARY TREND ANALYSIS FOR THE BLUE CREEK WATERSHED PROJECT

Pike County, Illinois

Phase I

Illinois Environmental Protection Agency
Division of Water Pollution Control
2200 Churchill Road
Springfield, Illinois 62706

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The purpose of this report is to present and briefly interpret preliminary trends in water quality data collected from project inception thru September 30, 1980 as part of the Blue Creek Watershed project. This discussion covers less than one full water years worth of data.

The primary purpose of this monitoring and evaluation project is to determine the actual yield of pollutants from a variety of agricultural practices to downstream receiving water and its effect upon the water quality and reasonable uses of the water resources. Monitoring and evaluation of actual Resource Management System implementation progress on sub-watersheds and yield of pollutants to the major tributary stream and public water supply lake will allow a reliable comparison of low and high-cost practices and downstream yield reductions, evaluation of cause and effect relationships between a variety of practices, determination of nonpoint source yields for the selection of lands requiring treatment to reduce water quality problems, and the impact of Resource Management Systems on both stream and lake quality. The observations and explanations are only preliminary in nature and should not be considered absolute conclusions.

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Phase I

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Rodney Mutz, Environmental Protection Specialist in Griggsville, administered the field sampling program within the watershed and assisted Bill Ettinger, IEPA Springfield Regional Office, in biological and lake sampling during the 1980 water year. Jane L. Johnson (IEPA) assisted in the sampling program. Many other individuals of the monitoring unit under the direction of Kenneth Rogers assisted in various aspects of the monitoring program. Carol M. Beim coordinated public participation efforts for IEPA.

Analyses of bacterial samples and of perishable and non-metallic chemical constituents in water samples were performed at the IEPA laboratory in Champaign, under the direction of Roy Frazier. Analyses of Kjeldahl-Nitrogen and designated metals in water samples were also performed at the Champaign laboratory. The IEPA Springfield Laboratory under the direction of John Hurley performed organic pesticide and PCB analysis of water samples.

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Perspective:

Half of the land in the nation is in agricultural or related uses. Agriculture is the most widespread cause of nonpoint source pollution. Initial "208" water quality planning efforts demonstrated that agricultural activities are a significant source of pollution in many parts of the country. The resources required to control agricultural nonpoint 'source' problems will be substantial. Both public and private investment must be utilized in the most cost-effective manner for that area.

Nonpoint Source (NPS) pollution prevents the optimal use of the water resources. This pollution can come from runoff of agricultural land or from groundwater return flow draining agricultural land. Surface runoff from agricultural land transports nutrients, pesticides, disease causing organisms, organic and inorganic-particulate material to water resources. Groundwater return flows can cause nutrient, pesticide and dissolved solids pollution problems. Eroded sediment is the most significant pollutant in terms of damage and total load carried by stream.

Cost-effective Resource Management Systems (RMS) must be installed to control these problems. A comparison of low and high-cost RMS's effectiveness in terms of water quality impacts must be made, so that the RMS implemented will be problem solving specific. The RMS's implemented in the Blue Creek Watershed are designed site and problem specific; thus the degree of effectiveness will vary when implemented under different climatic and geomorphilogical conditions. An attempt must be made to determine the effectiveness of RMS's at other locations, to enable the land owner/operator to implement the most reasonable RMS's for their area and problems.

Evaluation of NPS control projects is an integral component of the future implementation phase of NPS control programs (MIP, RCWP and ACP projects). Watershed evaluation programs must provide guidance and inputs to many administrative functions, such as: 1) investment of funds, 2) justification for allocation of these funds, 3) verification of overall program effectiveness, 4) evaluation of regional effectiveness of RMS's, and 5) informing local land owners and/or operators as to the effectiveness of their efforts to improve water quality (R. Hall and Shuyler, undated). The Blue Creek Watershed project will help provide this guidance.

The Blue Creek Watershed evaluation project is short-term due to the availability of funds. The incremental changes in the overall water quality, due to the RMS's implemented, may not be measurable within the 2 1/2 year project period because of the high degree of inherent variability within the system and the long response time of natural ecosystems to such subtle changes. Report of findings will be produced for each phase of the project.

Introduction

The Illinois Environmental Protection Agency (IEPA) in cooperation with United States Department of Agriculture Agencies, Agricultural Stabilization and Conservation Service (ASCS) and Soil Conservation Service (SCS), is evaluating the impact of Resource Management Systems (RMS's) implemented under the Agricultural Conservation Program Special Water Quality Project in the Blue Creek Watershed, Pike County, Illinois. The primary objective of this project is to identify the most viable agricultural non-point source (NPS) control strategy, demonstrate its effectiveness, develop a methodology to identify land causing water quality problems and to determine the appropriate Resource Management System for each farm unit. The purpose of this report is to present and briefly interpret preliminary trends in the water quality data collected from project (inception) May 1, 1980 thru September 30, 1980 as part of the Blue Creek Watershed Project.

Agriculture Nonpoint Source Pollution Problems

Agriculture is the most widespread cause of nonpoint source pollution. This pollution has many sources and effects. The two means of pollutant transport from source areas to surface water are runoff from agricultural lands and groundwater return flow draining agricultural lands.

A severe agricultural related problem is particulate transport of eroded soil. Nationwide, approximately half of the total sediment delivered to streams and lakes is from cropland. Eroded sediment is the major cause of damages and pollution from agricultural areas. Suspended solids have been identified as the most significant pollutant because of their physical properties, potential chemical interactions, and total loads. Suspended solids deteriorates water quality physically and chemically, this deterioration results in reduced use. Suspended solids are often associated with pollutants which cause water quality problems such as pesticides, nutrients and trace metals due to chemical interactions. The settling of suspended solids reduces the storage and flow capacities of our streams, lakes, and reservoirs. This reduction in capacity affects water supplies adversely and increases flood potential. It has been estimated that the total volume of eroded material is 700 times that of point sources. Due to the preferential delivery of silts, clays, and other chemically active amorphous materials the true impact of soil loss from agricultural lands is difficult to ascertain.

The deposition of organic particulate material in river channels, lakes, and reservoirs increases the oxygen demand in those areas thus reducing available oxygen required by aquatic organisms. Organic particulate material comes from plant residue, and unconfined livestock operations.

Nitrogen and phosphorus are essential nutrients for aquatic plant growth. It is estimated that 60% of the nitrogen and 42% of the phosphorus entering the nation's water courses come from agricultural lands (AWWA, 1967). Improper application of fertilizer can be a significant source of nutrients reaching surface water. Nutrients also come from runoff and leachate from animal waste in livestock operations or from the animal waste disposal systems. Elevated concentrations of nutrients in surface water can overstimulate growth of aquatic organisms, reduce available dissolved oxygen and reduce the potential for recreational use of the affected waters. This reduction in water based recreation results from degraded water quality, reduced visibility, poor aesthetic quality, algal blooms and undesirable debris.

Pesticides can be transported in runoff or associated with sediment. Some agricultural pesticides become toxic pollutants once they are transported from the field. These pollutants kill fish and other aquatic organisms. Some persist in the aquatic environment for extreme periods of time, so even very low levels of these pesticides are a hazard.

Bacteria, fungi and viruses cause disease in animals, humans and plants. Nonpoint sources of disease causing organisms are septic fields, farm and feedlot runoff and soils containing suspect organisms.

Description of Blue Creek Watershed

The Blue Creek Watershed consists of 7,012 acres in east central Pike County, Illinois. It drains into Pittsfield City Lake through Blue Creek and its numerous tributaries (refer to Figure 1). The Blue Creek Watershed is located approximately three miles northwest of Pittsfield and five miles south of Griggsville.

Pittsfield City Lake was constructed in 1961 by the Soil Conservation Service as a multiple purpose reservoir. It is utilized for recreation, flood control and as a water supply for the City of Pittsfield. There are no known municipal or industrial discharges to the Blue Creek Watershed upstream from Pittsfield City Lake.

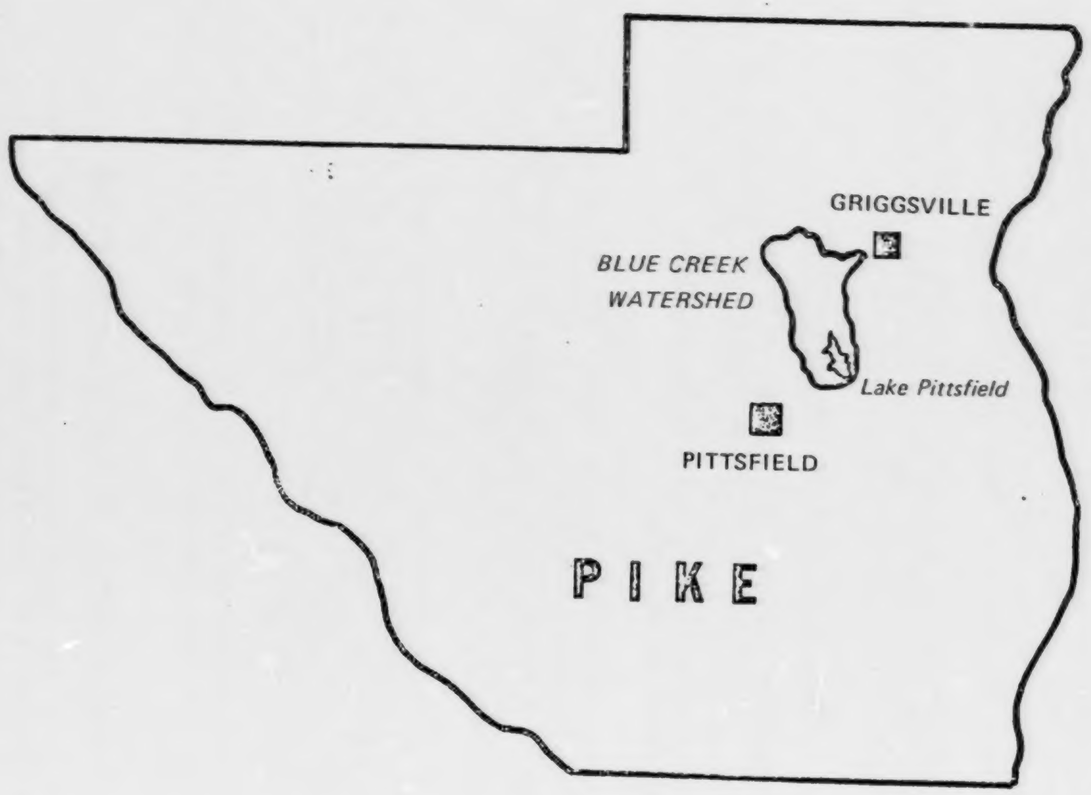
The land use in Blue Creek Watershed is predominantly agricultural (Table 1). The cultivation of row crops and production of livestock are important in the watershed. The terrain is hilly, and it has a high soil loss potential due to its steep slopes, fine-grained soils and agricultural land use practices. There are approximately 460 acres of hog and cattle feedlot operations on 21 farms.

For a more detailed description of Blue Creek Watershed and Pittsfield City Lake refer to Blue Creek Watershed Project, May 1979-October, 1980, (Davenport, 1981).

Purpose of Special Monitoring and Evaluation

The primary purpose of the monitoring and evaluation project is to determine the actual yield of pollutants (resulting from a variety of agricultural practices) to downstream receiving waters and its resulting effect upon the water quality and reasonable uses of the water resources. Monitoring and evaluation of actual Resource Management

Figure 1, Blue Creek Watershed, Pike County, Illinois.


GRIGGSVILLE
BLUE CREEK WATERSHED
Lake Pittsfield
PITTSFIELD
PIKE

Systems (RMS's) implementation progress on sub-watershed and yield of pollutants to the major tributary stream and public water supply lake will allow a reliable comparison of low and high-cost practices and downstream yield reductions. Evaluation of cause and effect relationships between a variety of practices, determination of NPS yields from farm lands requiring treatment to reduce water quality problems, and assessment of the impact of RMS's on both stream and lake quality.

TABLE 1

Land use/cover in the Blue Creek Watershed, 1981, by acres and percent

Land Use/ Cover	Blue Creek Watershed # of Acres	%
C-Sb	760.2	(10.8)
C-C-Sb	315.5	(4.5)
Continuous C	931.7	(13.3)
C-Sb-Gr	129.5	(1.8)
C-Sb-GR-M	466.1	(6.6)
C-Sb-Gr-M-M-M	601.3	(8.6)
C-Sb-Gr-M-M-M-M	756.5	(10.8)
Past/Hayland -- 80%	731.3	(10.4)
Past/Hayland -- 95%	788.0	(11.2)
Woodland Managed	543.6	(7.8)
Woodland Unmanaged	266.4	(3.8)
Wildlife	311.7	(4.4)
Farmstead	109.1	(1.6)
Feedlot	65.5	(0.9)
Water	236.4	(3.5)
Total	7012.8	100

Monitoring Strategy

The comprehensive monitoring network for the entire Blue Creek watershed was established by IEPA to document the basic hydrological, meterological and water quality factors of the project area (Figures 2 and 3). The duration, timing and quantity of NPS pollutants will be evaluated to determine land management effects on the water quality/quantity budget. The main stem of Blue Creek is monitored at two locations (Stations C & B) representing 50 and 70% of the drainage area respectively. One direct tributary representation 4% (470 acres) of the area (Station D) to the lake is monitored to determine the relative contribution of a major sub-basin directly entering the lake and provide data for unit size contribution purposes. Thus, spatial patterns, land use and physiographic characteristics can be evaluated relative to their actual and projected impacts on downstream water quality and lake characteristics.

Two sub-basins (Stations E & F) of 40 and 79 acres are being monitored concurrent with the major tributary monitoring. These areas are natural drainage networks. The areas were selected to provide comparative information on field level conditions representative of the physiography and land use activities impacting on water quality and uses. The sub-basin sites provide a comparative analysis of two different soil types, land management (RMS) and slope classes. The base-line monitoring of the sub-basins started in September, 1980.

Streamflow is measured on a daily basis. Runoff from rainfall and snowmelt is intensively sampled during the entire event because most of the sediment transported by streamflow is carried during a few large storms. During a runoff event, the sediment concentration usually changes abruptly and increases with increased discharge. The frequency and timing of the intensive water quality sampling program is keyed to storm events.

Sample analyses for chemical parameters in the tributary water quality monitoring will be identical to those in lake water quality monitoring. This allows nutrient budgets to be estimated for the monitored parameters. A complete parameter listing by station and sampling frequency is presented in tables 2, 3, and 4.

The lake is monitored at three locations to determine water quality and subsequent impacts of RMS's implementation. The results of the Water Year October 1, 1979 to September 30, 1980 (Water Year) are presented in the Results and Discussion Section.

TABLE 2

Parameter -- sampling frequency for the Blue Creek Project's Water Quality Analysis.

PARAMETER/FREQUENCY	DAILY	WEEKLY	EVENT
Total Suspended Solids	X	X	X
Total Volatile Solids	X	X	X
Ammonia-Nitrogen		X	
Total Kjeldahl Nitrogen		X	X
Total Phosphorus		X	X
Nitrite & Nitrate		X	
Dissolved Phosphorus		X	
Biological Oxygen Demand		X	
Chemical Oxygen Demand		X	X
Iron		X	
Potassium		X	

TABLE 3

Parameters measured monthly (Organics, Meals & HG^{+2})

ICAP

Barium
Boron
Cadium
Copper
Iron
Lead
Manganese
Nickel
Silver
Zinc
Beryllium
Calcium
Cobalt
Lithium
Magnesium
Potassium
Sodium
Strontium
Vanadium
Mercury (Not ICAP)

ORGANICS

Aldrin
Chlordane
DDT
Endrin
Heptachlor
Heptachlor epoxide
Lindane
Methorychlor
PCB's

TABLE 4

Blue Creek Project sampling schedule by frequency and location for chemical parameters. (Refer to Figure 1 for sampling location and Table 2 for a list of parameters by frequency)

FREQUENCY/SAMPLING LOCATIONS	A	B	C	D	E	F	LAKE SITES	COMMENTS
Daily		X	X					
Monday & Friday	X							
Weekly	X	X	X					Sample day is Wednesday.
Event	X	X	X	X	X	X		Station A is sampled twice daily 6 consecutive days after a storm.
Monthly Metals (ICAP)		X	X				X	
Monthly Organics		X	X				X	
Monthly							X	

The biological, stream geometry and channel characteristics, and computer-based modeling components of the Blue Creek Monitoring Program are described in the "Blue Creek Watershed Project, Pike County, Illinois, May, 1979 -- October, 1980" report.

Description of Monitoring Stations

Descriptions of the individual monitoring stations are presented below. Refer to Figure 2 for the location of the monitoring stations.

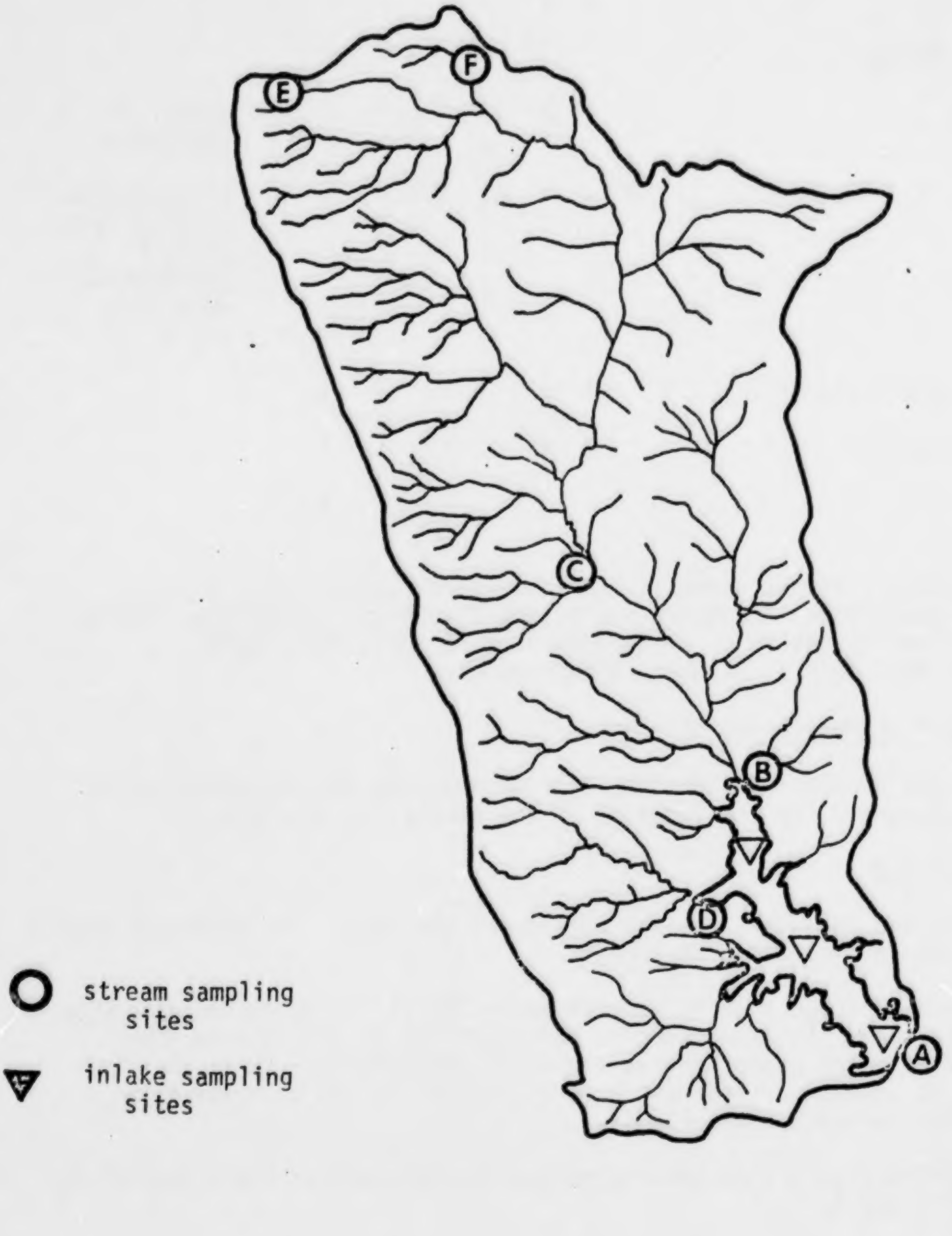
Stations A & B

Station A, the spillway, samples outflow of the lake. The drainage area is 7,029 acres including the lake.

Station B's drainage area is approximately 70% (4,858 acres) of the Blue Creek Watershed. It is located at the upper end of the lake on Blue Creek. This point characterizes the major lake inflow. Upstream of the causeway at Station B, sedimentation occurs due to the causeway flow restriction and backwater effects.

Sampling schedules and parameters monitored for Stations A & B are listed in Tables 2 and 4.

Figure 2. Map of Water Quality Stations in the Blue Creek Watershed in Pike County, Illinois


F
E
C
B
D
A
○ stream sampling sites
▽ inlake sampling sites

Station C

Station C is located at the Highway 107 bridge crossing Blue Creek. The most comprehensive sampling in the project area was conducted at this site. Streamflow is measured at Station C. Sampling frequency is daily, weekly and event related. The sampling schedule and parameters monitored are listed in Tables 2, 3 and 4.

This sub-watershed drains approximately 50% (3,339 acres) of the Blue Creek Watershed. Land use by acreage in this sub-watershed is presented in Table 5. In general, the relative proportion of each use is similar to the overall land use in the entire project area. Pasture and cropland comprise nearly 80 percent of the use with over two-thirds of the total in row crop production. Feedlot acreage is listed both under the woodland and farmstead land use category depending upon the type of operation.

TABLE 5

Land use by acreage for the sub-watershed drainage area to Station C in the Blue Creek Watershed as of October 1, 1981.

Land Use	Acreage	Percent Total
Cropland	2006	60.0
Pasture/Hayland	768	23.0
Woodland	288	8.6
Wildland	196	5.9
Farmstead	33	1.0
Feedlot	48	1.5
Total	3339	100

Station D

Station D is located on the western side of Pittsfield City Lake. Runoff resulting from rainfall-events and snowmelt is sampled at Station D. Parameters monitored are listed in Tables 2 and 4.

Land use in the lowlands is predominately woodland and pasture with rowcropping dominant on the sloping lands and ridgelands. There are three feedlot operations in this sub-basin. The drainage area of this sub-watershed is 470 acres. It drains directly into the lake.

TABLE 6

Land use by acreage for the sub-watered drainage area to Station D in the Blue Creek Watershed as of October 1, 1980.

Land Use	Acreage	Percent Total
Cropland	248	52.7
Woodland	142	30.2
Pasture	80	17.1
TOTAL	470	100

Station E*

Station E is located in the northwestern part of the watershed. Runoff resulting from rainfall-events and snowmelt is sampled at Station E. The parameters monitored for are listed in Table 2.

Station E consists of one 40 acre field draining into an unnamed channel. Table 7 lists the past practice, present practice and the average annual erosion rate by practice. The present practice has reduced average annual erosion by 40%. This soil loss is still approximately 3 times the allowable maximum soil loss per acre tolerance loss (T) a given soil may experience and still maintain its productivity over an extended period of time as defined by the Soil Conservation Service.

*Station E originally was located in the southwest part of the waterhshed, but due to monitoring difficulty it was moved to its present location.

TABLE 7

Past practice, present practice and the associated average annual erosion rate by practice for Station E's drainage area.

SIZE (acres)	$\bar{X}$ ANNUAL EROSION RATE* (TONS/ACRES)	PAST PRACTICE
40	24 Tons	C-Sb Rotation Spring Plow Up & Down the Slope
		PROPOSED PRACTICE
	14.5	C-Sb-6r Rotation Chisel Plow in the Fall Disk Twice & Plant; 1-2000 lbs. Residue Left on the Ground

*Calculated using the USLE C; Corn, Sb; Soybean, Gr; Wheat

Station F

Station F is located in the northern part of the watershed. Runoff resulting from rainfall events and snowmelt is sampled at Station F. The parameters sampled for are listed in Table 2.

Drainage area of Station F consist of 79 acres draining four different fields. Table 8 lists the past and proposed practices and the average annual erosion rate by practice for each field. The implementation of proposed practices will reduce average annual erosion by 77%. The resulting soil loss is below the maximum allowable soil loss tolerance per acre (T).

TABLE 8

Past practices, proposed practices and the associated average annual erosion rate by practice for fields in Station F's drainage area.

FIELD NUMBER	SIZE (acre)	$\overline{X}$ ANNUAL EROSION RATE* (TONS/ACRE)	PAST PRACTICES
#2	14.6	19-20	C-Sb Rotation Spring Plow Across the Slope or Disk - Chisel - Disk Twice - Plant
#3	19.8	10-11	C-Sb-Gr-4 yrs. Grass Rotation - Spring Plow Across the Slope
#4	34.1	19-20	C-Sb Rotation Spring Plow Across the Slope or Disk - Chisel - Disk Twice - Plant
#5	10.0	30-33	C-Sb Rotation Spring Plow Across the Slope or Disk - Chisel - Disk Twice - Plant
			PROPOSED PRACTICES
#2	14.6	4.5-5.0	C-S b-Gr Rotation Conservation Tillage 1-2,000 lbs. Residue on Contour
#3	19.8	3.5-4.5	C-Sb-Gr-7 Yrs. Grass Rotation - Conservation Tillage 1-2,000 lbs. Residue on contour

FIELD NUMBER	SIZE (acre)	$\bar{X}$ ANNUAL EROSION RATE* (TONS/ACRE)	PAST PRACTICES
#4	34.1	4.5-5.0	C-Sb Rotation Conservation Tillage 1-2,000 lbs. Residue on Contour
#5	10.0	4.5-5.0	C-Sb Rotation Conservation Tillage 1-2,000 lbs. Residue on Contour with Grassed Back Slope Terrace

*Calculated using the USLE C; Corn, Sb; Soybean, Gr; Wheat

Monitoring Methods and Procedures

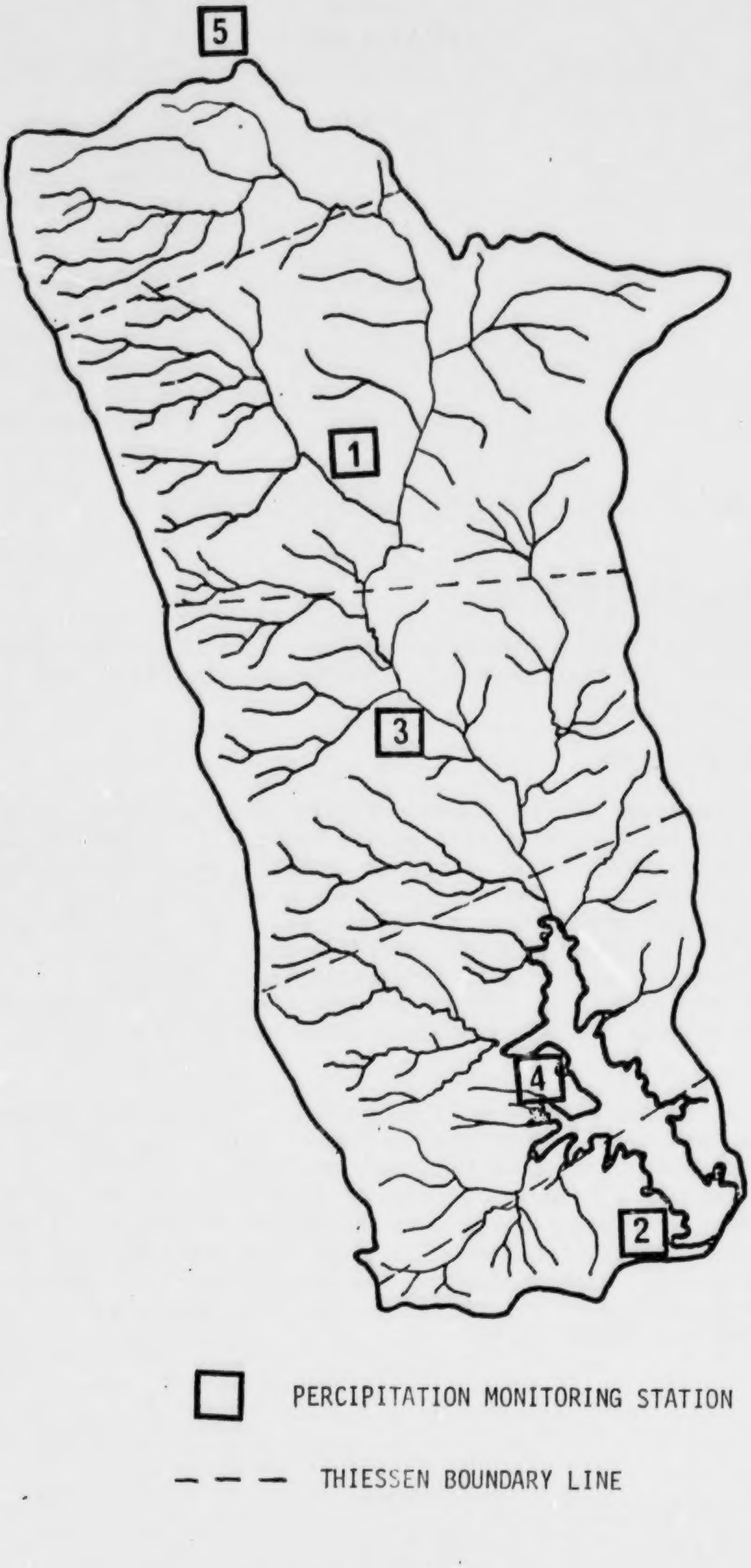
Methods used for field and laboratory procedures are those accepted for agricultural related hydrology research. Analytical techniques are documented, but not detailed.

Precipitation Measurements

Precipitation is measured at five locations (Figure 3) on the watershed using Belfort Universal Recording rain gauges (weighing -- type gauge). Annual precipitation, total amount of storm rainfall, rate of delivery, duration and distribution in time and space are directly measured or calculated. For annual precipitation, the values of all five rain gauges are averaged. The individual station records are utilized when determining storm variation for soil erosion/sediment delivery calculations and modeling. Two methods are utilized when analyzing storm variation, these methods are depth-area-duration and storm frequency analyses.

A depth-area-duration analysis is used to determine the maximum amounts of precipitation for storms of various durations distributed over various parts of the watershed. The storm frequency analysis is used to determine the frequency with which a storm of a certain magnitude will be equaled or exceeded. It was necessary in the design of structural RMS to know the frequency with which storms of a given size and intensity will be equaled or exceeded. When evaluating the effectiveness of individual RMS's, the storm frequency of the measured storm must be determined to see if it exceeded the design storm.

Figure 3. Location of Precipitation Monitoring Stations Within the Blue Creek Watershed.


5
1
3
4
2
☐ PERCIPITATION MONITORING STATION
— — — THIESSEN BOUNDARY LINE

Flow Measurement

There are four automated flow gauging stations installed in the Blue Creek Watershed. The two major streamflow gauging Stations (C & D refer to Figure 2) consist of stilling wells, (diameter; Station C, 24 in.; Station D, 18 in.) and a Leopold Stevens continuous water level recorder. The stilling well is a corrugated pipe installed to a level below the river bottom and connected to the river flow by underground pipes. The stage in the river is the same as the elevation of the water in the corrugated pipe (stilling well), which is recorded by the Leopold Stevens recorder. The diameters of the stilling wells vary, due to the size of upstream drainage area. The river banks and channel are undisturbed. The remaining two automatic stations are field runoff gauging Stations (E & F) each have a 3.0' H-Flume and a watch-dog type Leopold Steven water level recorder. These Leopold-Stevens instruments record the level (stage) of runoff continuously on a strip chart after being activated. Flumes were needed at these locations to enable highly accurate runoff estimates. A flume is a device for controlling the flow by keeping the water moving for some distance in a constant cross-sectional area. These flumes were designed to minimize the errors in determing the relation of runoff to stage. Leopold Stevens' strip charts are digitized by the Illinois State Water Survey (ISWS) under the direction of Ming Lee for subsequent analysis.

To record maximum streamflow during runoff events crest gauges have been installed at five locations on the main stem of Blue Creek. The high water leaves a mark on the gauge that the field sampler records when collecting stream bed samples for analysis after runoff events. Only the highest streamflow leaves a mark. The crest gauge measurements are checked against the Leopold-Stevens water level records for accuracy.

Streamflow at Station C is estimated as a function of stage based on measured discharge using a velocity current meter during time of known stage (Holton et al., 1968). A pygmy current meter is used to measure velocity. It works on the principle of a rotating cup-propeller emersed in the stream. Each rotation of the propeller is counted and velocity is computed from a calibration equation furnished with the meter. The stream stage was continuously measured starting in November, 1979 at Station C. At Station D, direct streamflow measurement is not feasible. The site has three parallel 66-inch corrugated pipes. Because of this situation a USGS indirect method will be utilized to estimate stream discharge. Station D was not fully operational before October 1, 1980. At Stations E and F, the flumes are rated 30' H-Flumes as such, the discharge hydrographs (discharge is plotted over time the resulting curve is a hydrograph) can be estimated directly from published rating curves and recorded stage data. Stations E and F became operational in September, 1980.

The overflow of Pittsfield City Lake is monitored at the spillway, Station A. The lake level is recorded daily by the water treatment plant operator. These readings are used in conjunction with the spillway rating curve to estimate lake outflow. Streamflow entering the lake at Station B will be estimated by extrapolation of streamflow at Station C.

Field methods used in this study are a recognized compromise between the accuracy and precision of field sampling and the funds available for the study. Generally, estimations of streamflow using uncontrolled sections of channel have an accuracy of about ± 10%. When flood events occur which are significantly greater than any measured streamflow, the accuracy of estimation of peak flow is unknown. As flow durations of extreme flood events are short, the overall accuracy of a water balance is much better than prediction of short-term peak flows.

Watershed Water Quality Sampling

Water quality monitoring was initiated in May, 1980. Four ISCO automatic water samplers (model 1680) and one Sigma automatic device sampled streamflow during runoff events. The ISCO samplers were located at gauging Stations C, D, E and F. At Stations C and D, the samplers were programed to collect 250 millimeters (ml) of streamflow each 7 1/2 minutes compositing two samples per bottle. Each sampler would collect 7 1/2 minute samples for a 7-hour period once started. At Stations E & F, the samplers were programed to collect 250 ml of streamflow each 7 minutes, compositing two samples per bottle. Each sampler would collect 7 minute samples for a 6.5 hour period once started. The Sigma sampler was located next to the dam spillway (Station A) to sample lake outflow resulting from storm or snowmelt events. Due to mechanical problems, Station A is now sampled manually twice a day for six days after rainfall events.

Electrical triggering devices initiates sample collection by activating each automatic water sampler when the water level reached a predetermined stage which varied by location and season. Stages were selected which would allow the complete runoff event at that location to be sampled. However, the duration of some runoff events exceeded the sampler capacity or mechanical problems with the sampler, prevented sampling of the complete hydrograph.

Weekly, daily and monthly samples at Stations A, B, and C were collected using a hand-held bottle or weighted bottle holder as appropriate, and composited in a churn sample splitter in accordance with established IEPA procedures (Walton, 1979).

Samples collected by the ISCO automatic water sampler are drawn by a peristalic pump through 1/4 inch, (I.D.) tygon tubing that extends from each sampler to the thalweg (deep spot) of the stream course being sampled. Before and after the sample is taken, the pump air purges the suction line, thus minimizing the possibility of cross section contamination. The weighted polypropylene strainer at the end of each suction line is suspended into the stream from an overhead guiding device.

A major drawback of the suspended sediment sampling procedures is that they do not permit sampling close to the streambed. Currently available suspended-sediment samplers only collect water samples from the surface to a point about 0.3 to 0.5 feet above the bottom. These samplers and sampling procedures do not allow the sampling of the layer of streamflow closest to the bottom which is carrying the greatest concentration of coarse particles (bedload). Therefore, bedload is not measured as part of the water quality monitoring. As part of the Stream Geometry and Channel Characteristics Study (Davenport, 1981), particle size distribution analyses of bed material at five sites in the main channel of Blue Creek enables the contribution of bed material to the total suspended load to be estimated.

Water samples sent to the laboratory for routine analyses were collected in plastic bottles with appropriate preservative (Appendix Section). Pesticides and polychlorinated biphenyls (PCB's) samples were collected with specially prepared quart bottles using methods described above and composited directly into a one gallon glass bottle. Fecal coliform samples were collected in specially prepared glass bottles.

Dissolved oxygen, temperature, pH, and conductivity were measured by a meter in the field. Water temperature and dissolved oxygen concentrations were determined at each station using a Yellow Springs Instruements (YSI) Model 57 dissolved oxygen meter. The pH was measured with a Sargent-Welch Model PBL pH meter. Specific conductance was measured using an Electrolytic Conductivity Measuring Set, Model MC-1, Mark V Conductivity meter, manufactured by Kent Electronic Instruments Limited (Chestsey, England). All meters were calibrated in the field consistent with the Agency Field Methods Manual (Walton, 1979).

Lake Water Quality Sampling

Ambient lake water quality is the result of a complex of possible interactions between numerous physiochemical, environmental, and biological constitutents, all of which may vary in a spatiotemporal manner. "Fundamental data used in the determination of water quality are obtained by the chemical analysis of water samples in the laboratory or on-site sensing of chemical properties in the field (Hem 1979.)" An ambient water quality data base is an essential prerequisite to evaluating the impact of RMS's upon lake water quality, developing rational lake or reservoir management strategies. Of necessity, an acceptable data base should include (but not necessarily be limited to) an assessment of the following types of in-lake parameters:

1. Nutrients, physical, and chemical factors that may limit, inhibit, or stimulate plant growth;
2. Factors which affect water transparency and, thus, primary production rates;
3. Extent and degree of vertical stratification and those constituents whose solubility is affected by changes in redox potential;
4. Potential toxic contaminants such as heavy metals, organochlorine compounds, etc.

Field Collection (IEPA, 1980)

Lake sampling was routinely accomplished by boat with a team of two people. Sampling locations were selected to best represent overall lake quality and were based upon lake morphometry, potential input sources, known hydrological characteristics and on-site judgment of the investigators. Three sites were sampled on Pittsfield City Lake.

Chemical and physical measurements made in the field included pH, alkalinity, conductance, water transparency (Secchi), dissolved oxygen, temperature, and site depth. Observations of the weather conditions including air temperature, wind speed and direction, precipitation, and percent cloud cover were recorded on field data forms. Lake color (apparent color), turbidity, aquatic flora, water levels, and general lake usage were noted as appropriate.

Water transparency was measured with an eight-inch-diameter Secchi disc. The disc was lowered until it disappeared from view and the depth of immersion was noted. The disc was lowered further and then raised slowly until it reappeared. This depth was noted. The average of these two observations was recorded as the Secchi disc transparency. Site depth was determined using a weighted line calibrated in feet with results estimated to the nearest tenth of a foot.

Water samples were collected at the top of the water column (approximately one foot below surface) and two feet above the bottom when site depth exceeded ten feet. All water samples, except mercury and bacterial, were collected with a 4.2-liter plastic Kemmerer water sampler. Top water samples were taken by immersing the open sampler in the horizontal position to a depth of one foot and closing by hand. When required, bottom samples were taken by triggering the sampler in the conventional manner. All water samples collected by the Kemmerer, with the exception of water destined for dissolved phosphate analysis, were placed in ice, and taken to the laboratory for analysis. Dissolved phosphate water samples were first filtered through 0.45 um pore size Type MF-Millipore filters. Mercury and bacterial samples were collected from surface waters by hand-held bottles.

The pH of water samples was determined using a Sargent-Welch Model PBL pH meter. Alkalinity was determined from titration of a 10 ml sample with 0.02 NH_2SO_4 using phenolphthalein and bromcresol green-methyl red indicators. Results were expressed as mg/l $CaCo_3$. Specific conductance was determined using either a Yellow Springs Instruments (YSI) Model 33 S-C-T Meter or Electrolytic Conductivity Measuring Set, Model MC-1, Mark V conductivity meter manufactured by Kent Electronic Instruments Limited (Chertsey, England). Air temperature was taken with a mercury-type field thermometer. Water temperature and dissolved oxygen concentrations were taken *in situ* using a YSI model 57 dissolved oxygen (DO) meter; measurements of DO and temperature were taken at the surface, one foot below the surface, and at two-foot intervals thereafter (i.e., 3 ft., 5 ft., 7 ft., etc) and discontinued beyond depths which recorded 0.0 mg/l dissolved oxygen. The DO, pH and conductivity meters were all calibrated in the field in accordance with IEPA sampling procedures (Walton, 1979).

Laboratory Procedures (IEPA, 1980)

Upon return to the regional field office, samples were refrigerated or frozen and transported to the appropriate lab for analysis. Table 28 in the Appendix Section, lists all parameters monitored, the laboratory performing the analysis, and provides a brief outline of the specific analytic procedure used in each analysis. Other pertinent information such as detection limits and General Use Standards are also included.

RESULTS AND DISCUSSION

Water quality sampling in the Blue Creek Watershed started in May, 1980 and continues to the present. Streamflow samples are collected on a daily, weekly, monthly and a storm event basis. All laboratory analyses were performed by Illinois Environmental Protection Agency's laboratories. All water quality data is presented in the Appendix Section.

Three periods, based on the amount of surface cover and land management activities, were selected for evaluating seasons and variation in streamflow constituent concentrations and transport. These periods were selected to conform to the normal agricultural management pattern of the watershed. These periods are: P1-fertilizer, seedbed, and establishment period (April-June); P2-reproduction and maturation period (July-November); and P3-residue period (December-March). Alberts (1978) used this three season concept to examine seasonal losses of nitrogen and phosphorus in Missouri. There will be some variation in period length from year to year due to climatic factor; in Water Year 1980 this variation was minimal.

Watershed

This discussion covers less than one full Water Year's worth of data. The observations and explanations are only preliminary in nature and should not be considered absolute conclusions.

Land Treatment

RMS's are being developed by SCS to meet the goals of the project and concerns of the people. The Blue Creek Special Water Quality Project is an ASCS cost-share program that assists farmers in installing conservation practices to protect the resource base and improve water quality. The SCS is working with landowners to control erosion and also with livestock producers to control problems from waste runoff and erosion associated with livestock operations.

The physical effects of soil and water conservation practices are primarily based on control of runoff, rain splash energy, and soil structure. Most RMS's are designed to control either: 1) detachment and transport or 2) only transport of soil particles.

RMS's can be divided into 2 groups. The first, cultural practices, are nonstructural in nature. This group includes no-till, conservation tillage, contouring and stripcropping. The second group consists of structural practices which usually require off-farm equipment for construction. The practices in this group include terraces, grassed waterways, lagoons, and filter strips. Economically, the two classes of practices can be distinguished on the basis of both initital cost and recurring costs. Structural practices are characterized by a relatively high initial cost and lower annual costs, representing maintenance costs. Cultural practices, such as the alteration of tillage system or removal of land from production for some purpose have a recurring annual cost based on the value of production cost through the application of the practice. These costs in agricultural situations are dependent on the costs of inputs to farm production and the value of farm products to be sold (Lake, 1977).

Majority of conservation practices installed as of September 30, 1980 were applied southeast of Highway 107 and below Station C (Table 9, Figure 1). A summary of conservation practices implemented in the Blue Creek Watershed as of September 30, 1980 is in the Appendix Section. Land with conservation practices above Highway 107 represented only 9 percent of the crop and pasture land.

TABLE 9

Summary of conservation practices applied in Blue Creek Watershed in relation to Highway 107 (Station C)

Conservation Practice	Below Southeast of Highway 107 Acres Treated	Northwest of Highway 107 Acres Treated
Critical area seeding and pasture improvement	32	0
Critical area seeding	0	3
Contour	172	78
Stripcropping	43	0
No-till	146	71
Reduced tillage	0	31
Terraces	178	4
Structures	64	0
Pond	1	0
Lagoon		2
Vegetative Filter Strip	4	0
Waterway	29	51
Permanent Vegetative Cover	0	12
TOTAL	669	252

Precipitation

Rainfall data for the Water Year was measured in 5 minute intervals at all recording gauge stations in the watershed. The National Oceanic and Atmospheric Administration's, Griggsville, Illinois Weather Reporting Station records were utilized to determine the historic precipitation pattern in the Blue Creek Watershed. Figure 4 is a graph of the normal precipitation at Griggsville Water Year monthly precipitation in the Blue Creek Watershed is shown in Table 10. Figure 5 is an example of precipitation resulting from a rainfall event on September 16, 1981.

Wischmeier (1965), defined a storm as period of precipitation of 1.27 cm (0.5 in.) unbroken by 6 hours of non-measurable precipitation. This definition was used for rainfall differentiation. Table 11 summarizes the storm and non-storm rainfall by month for Water Year 1980. The percentage of monthly precipitation that came in storms ranged from 0% (January and February) to 94.5% (December), it averaged 49%.

In general, below normal precipitation was observed in the basin throughout the year. In addition, wide variation in rainfall was measured on several occasions and Figure 5 indicates the spatial variability.

Figure 4. Normal and Water Year Precipitation in the Blue Creek Watershed

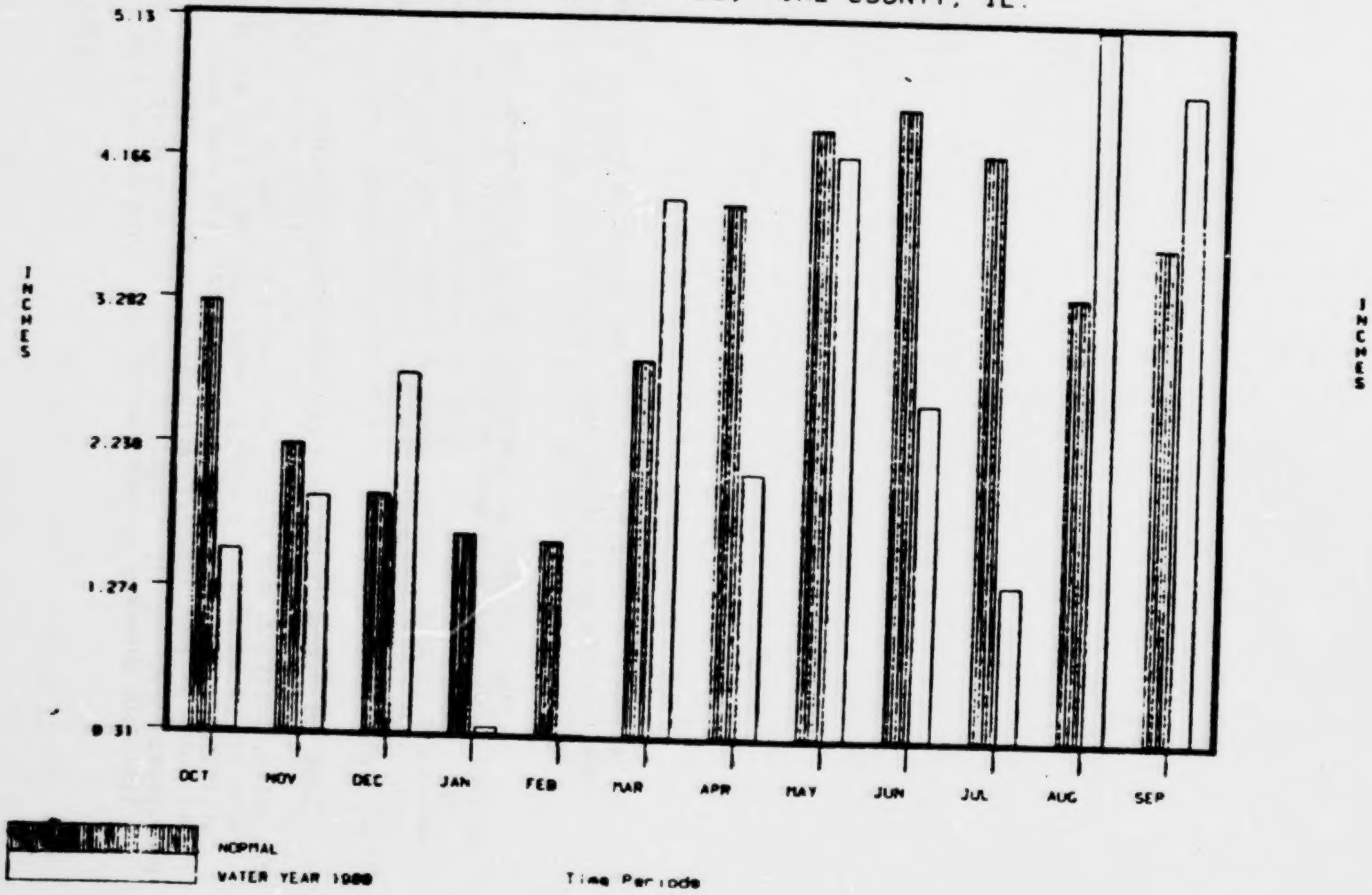

MONTHLY NORMAL AND WATER YEAR 1980 PRECIPITATION AVERAGES
IN THE BLUE CREEK WATERSHED, PIKE COUNTY, IL.

TABLE 10

Water Year 1980 monthly and long-term (1941-70) precipitation averages measured in Griggsville, Illinois.

	NORMAL (Griggsville Station)		1979-80 (Watershed Stations Average)	
	(in)	(cm)	(in)	(cm)
October	3.18	8.07	1.52	3.86
November	2.23	5.66	1.88	4.78
December	1.9	4.83	2.71	6.88
January	1.64	4.16	0.35	0.89
February	1.60	4.06	0.31	0.79
March	2.82	7.16	3.90	9.91
April	3.87	9.83	2.07	5.26
May	4.39	11.12	4.21	10.69
June	4.55	11.16	1.35	6.48
July	4.24	11.08	2.55	3.43
August	3.29	8.36	5.13	13.03
September	3.64	9.24	4.69	11.91
Annual	37.35	94.73	30.67	77.91

TABLE 11

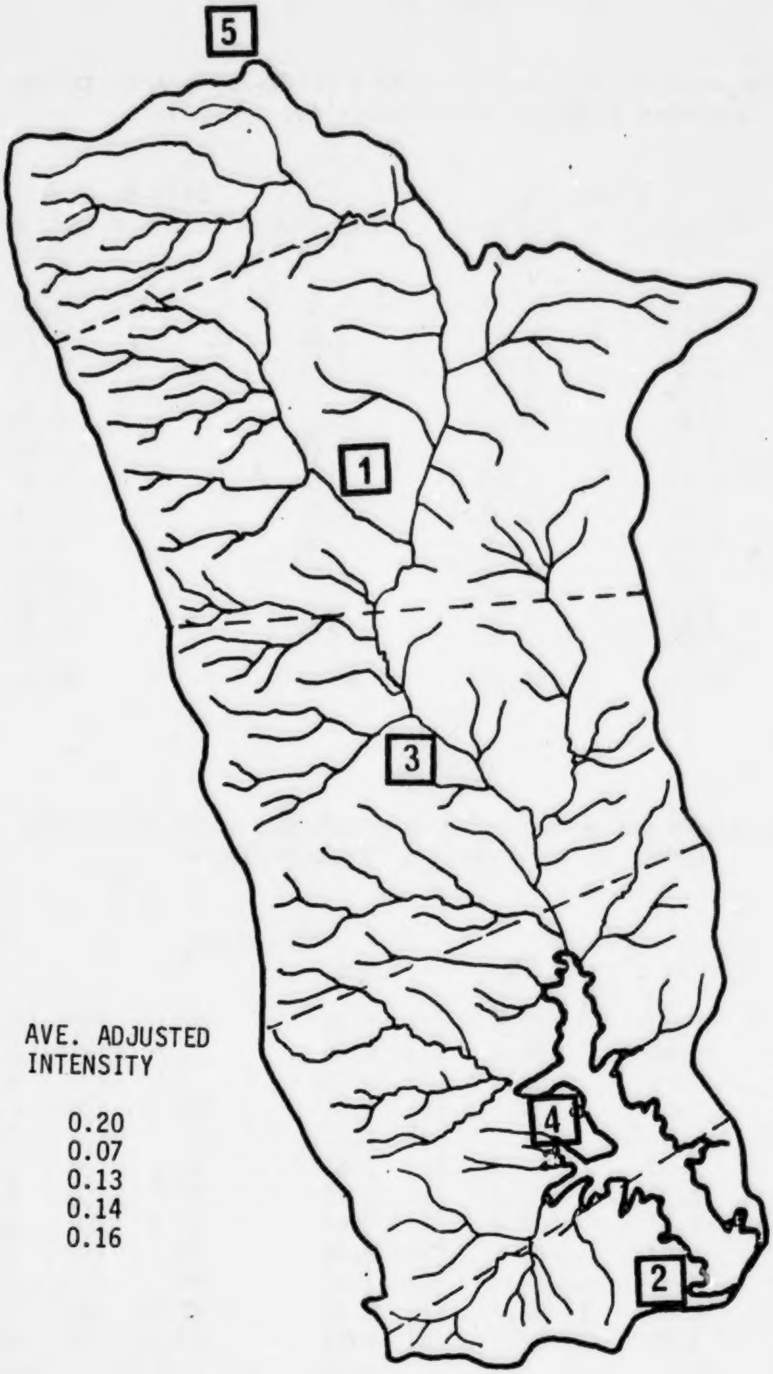
Monthly, storm and non-storm precipitation; Water Year 1980. Number of observations in parenthesis.

Month	Storm in	Storm %		Non-Storm in	Non-Storm %		Total in
October*	1.10	72.4	(2)	0.42	27.6	(3)	1.52
November*	0.50	26.6	(1)	1.38	73.4	(7)	1.88
Decmeber	2.56	94.5	(3)	0.15	5.5	(1)	2.71
January	-0-	-0-	(0)	0.35	100	(3)	0.35
February	-0-	-0-	(0)	0.31	100	(1)	0.31
March	2.03	52.1	(2)	1.87	47.9	(9)	3.90
April	1.29	62.3	(1)	0.78	37.7	(3)	2.07
May	3.67	87.2	(4)	0.54	12.8	(3)	4.21
June	1.57	61.6	(2)	0.98	38.4	(4)	2.55
July	-0-	-0-	(0)	1.35	100	(9)	1.35
August	2.93	57.2	(3)	2.20	42.8	(7)	5.13
September	3.85	82.1	(4)	0.84	17.9	(5)	4.69
	17.9			9.37			30.67

*Information from Pittsfield gauge

From December to September 49.7% of all measured precipitation came in storms.

Figure 5. Spatial Variation of Precipitation Resulting From a Rainfall Event on September 16, 1980



STATION	TOTAL RAINFALL	AVE. ADJUSTED INTENSITY
1	1.29	0.20
2	0.79	0.07
3	1.23	0.13
4	1.10	0.14
5	1.44	0.16

☐ PERCIPITATION MONITORING STATION

— — — THIESSEN BOUNDARY LINE

Streamflow

Streamflow consists of water from channel interception, overland flow, interflow (where it occurs), and subsurface flow. The route followed by a water particle from the time it reaches the ground until it enters a stream channel is complex. There are three main routes of travel overland flow, interflow and subsurface flow. Overland flow is that water which travels over the ground surface to a channel, it transports soil particles, crop residue, and chemicals to the water course. Interflow is the water which infiltrates the soil surface and moves laterally through the upper soil layers until it enters a stream channel. Subsurface flow is groundwater that discharges into a stream. Streamflow, according to Pilgrim et al. (1978), cannot be separated into distinct quantities from different sources, but inferences concerning influences of sources on the time of distribution of water arriving at the stream channel may be made. Soil depth controls, to a large degree, the quantity of water that will be stored in the soil of a watershed and the duration of release to streams thru subsurface flow or its use by vegetation.

Blue Creek was surveyed and channel cross-sections of the stream were made. Using the Soil Conservation Service's WSP2 Computer Program, a stage-discharge relationship was developed. Several cross-sections had to be taken downstream of Station C because no stage-discharge relationships were known. The water surface profile calculations began at critical depth and since the calculations began downstream, the stream channel geometry would govern the flow regime so that by Station C the stage should be reasonably close to the actual stage for a particular discharge. Lake Pittsfield's influence may be felt at Station C so therefore, a refinement was in order. With the results from the first run of the computer program as a starting point, a second computer run was made. The resulting stage-discharge was then calibrated. The calibration was done by comparing the monthly runoff at Station C computed using the stage-discharge relatiobship obtained from WSP2 with the runoff at Bay Creek. Various ratios of the stage-discharge relatiobship were used until there was agreement between the discharges at Station C and at Bay Creek.

There were no stage measurements made at Station B. It was then necessary to find a method to determine discharge at this site in lieu of any stage measurements. It was felt that Station B must be related to one or both of the other two stations. Station A may not be representative due to pumpage, evaportation and direct rainfall on the lake. Therefore, Station B was related to Station C in the analysis. The relationship that was used was the ratio of drainage areas and runoff.

Discharge @ B = Discharge @ C* Drainage Area @ B/Drainage Area @ C

Though Station C had hourly readings, only daily averages were used which minimized an errors.

Daily stage readings were recorded at Station A. Knowing the geometry of the spillway, a stage-discharge relationship was calculated. The instantaneous stage reading was assumed to be a daily average since the lake stage response is so slow. (Lee, personal communication).

A summary of daily streamflow data measured at Station C is presented in the Appendix Section. Table 12 shows average daily, monthly maximum and minimum streamflow at Station C from November, 1980 thru September, 1981. High flows can be expected from February through June while low flows usually occur during July and August.

TABLE 12

Average daily, monthly maximum and minimum streamflow in cubic feet/second (cfs) and monthly total flow measured at Station C on Blue Creek, Pike County, Illinois-Water Year, 1980

Month	Average Daily (CFS) Streamflow	Monthly Maximum (CFS) Streamflow	Monthly Minimum (CFS) Streamflow	Monthly Total (CFS-DAS)
October	*	*	*	*
November	*	*	*	*
December	16.2	48	13	503
January	15.9	18	13	493
February	20.1	83	16	583
March	24.8	375	19	769
April	26.7	448	19	800
May	21.6	564	16	671
June	22.8	442	14	685
July	11.9	28	6	368
August	11.9	136	2	368
September	18.6	606	11	557

*Information incomplete or not available

Storm Events and Runoff

Runoff is a summary term used to refer to the various processes which ultimately produce streamflow. The word "runoff" by itself does not convey any idea of the source or timing of the water yielded by a basin. Total precipitation, antecedent precipitation, soil moisture, ground cover, and storm characteristics influence the quantity of streamflow produced by any given event. Wischmeier (1965) definition of a storm described earlier is used for this analysis.

The source area of runoff in a watershed expands and contracts according to rainfall rates and capacity of the soil to retain and release water (Dunne, 1978). The variable source area concept explains how a channel network grows to many times its average perennial dimensions during storm runoff as streams become both longer and wider. The variable source concepts applies to the Blue Creek Watershed because infiltration is not a limiting factor (Dunne, 1978). The variable source area concept is important when attempting to ascertain streamflow constituent transport.

Table 13 is a summary of all storms measured in the Blue Creek Watershed during Water Year 1980. Total event precipitation is the basinwide area weighted (Thiessen method utilized) total precipitation. There was considerable variability between precipitation recording stations (Figure 5).

The largest storm event measured was on May 17, 1980 total event precipitation was 1.67 in. (4.24 cm), it produced a peak discharge of 564 cfs (15.46 cum/s). The smallest storm was measured on May 31, 1980, total event precipitation was 0.54 in (1.37 cm) and it produced a peak discharge 5 cfs (1.47 cu.m/s). The smallest peak discharge, 1 cfs (0.03 cm.m/s), was measured on August 4 it resulted from a total rainfall of 0.72 in. (1.83 cm) this followed in a lengthly dry period. The largest peak discharge, 606 cfs (17.15 cu.m/s), resulted from 1.29 in (3.28 cm) of rainfall on September 16.

Figure 6. Scatter Plot of Peak Discharge vs. Total Event Participation

PEAK DISCHARGE VS. STORM PRECIPITATION FOR WATER YEAR 1980

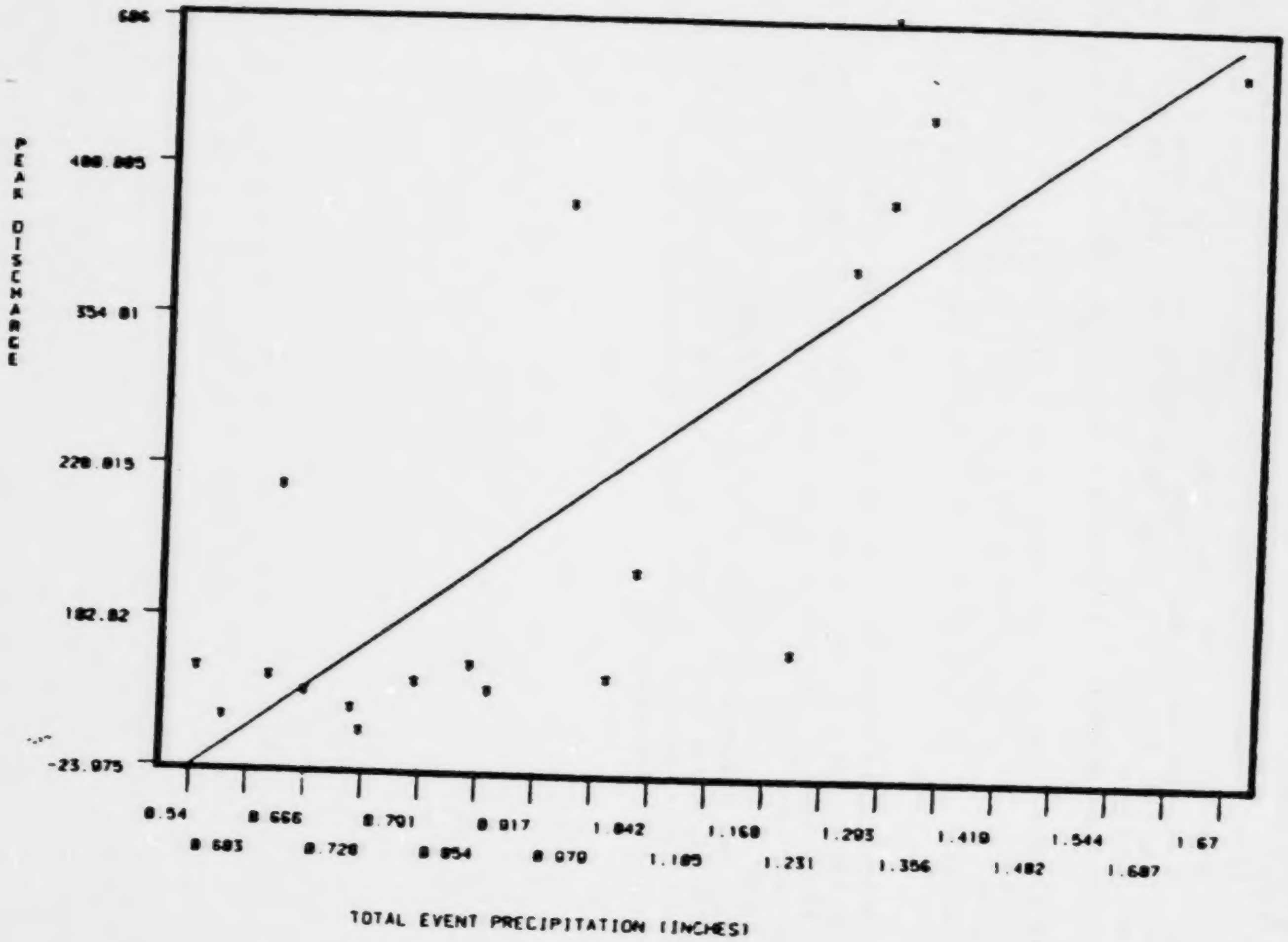


TABLE 13

Summary of all storms measured in the Blue Creek Watershed during Water Year 1980

Date	Length of Rainfall (hrs)	Total Event Precipitation (in)	(cm)	Rank	Peak Discharge (cfs)	(cu.m/s)	Rank
12-22	5.5	0.71	1.80	14	20	0.57	17
12-23	14.0	0.86	2.18	10	37	1.05	15
12-24	10.0	0.99	2.51	8	48	1.36	12
03-24	10.0	0.78	1.98	12	43	1.22	14
03-30	5.4	1.25	3.18	5	391	11.07	6
04-07	4.8	1.29	3.28	3	448	12.68	4
05-12	1.7	0.84	2.13	11	58	1.64	10
05-17	13.1	1.67	4.24	1	564	15.96	2
05-23	6.3	0.62	1.57	17	46	1.30	13
05-31	1.3	0.54	1.37	19	52	1.47	11
06-01	2.8	0.94	2.51	9	442	12.51	5
06-04	1.3	0.63	1.60	16	204	5.77	7
08-04	1.7	0.72	1.83	13	1	0.03	19
08-15	6.5	1.19	3.02	6	72	2.04	9
08-16	3.3	1.02	2.59	7	136	3.85	8
09-01	5.1	0.57	1.45	18	123	0.34	18
09-04	6.3	0.66	1.68	15	34	0.96	15
09-05	4.4	1.33	3.38	2	521	14.74	3
09-16	8.2	1.29	3.28	3	606	17.15	1

There is a very strong relationship between total event precipitation and peak discharge in the Blue Creek Watershed. Figure 6 is a scatter plot, with a regression line, of peak discharge vs. total event precipitation. The correlation coefficient of the regression line is 0.80 ($r^2 = 0.64$). This is significant at the 99.9% level.

The rainfall runoff ratio ranged from 1.5% in July to 64.5% in February and averaged 8.0% for the ten month period.

Suspended Matter

Total suspended solids (TSS) in the water column are composed of volatile and non-volatile fractions. Volatile suspended solids (TVS) are organic in nature, while non-volatile solids (NVS) are generally inorganic. Suspended matter impacts freshwater ecosystems biochemically, chemically, physically, and biologically (Table 14). Suspended matter can increase the cost of obtaining a suitable water supply for some users. The National Academy of Science -- National Academy of Engineering Committee's (NAS-NAE) Working Party on Water Quality Criteria for European Freshwater Fish has arbitrarily defined four degree of risk to fisheries categories and estimates of the range of suspended solid concentrations that corresponds to each;

(1) There is no evidence that concentrations of suspended solids less than 25 mg/l have any harmful effects on fisheries.
(2) It should usually be possible to maintain good or moderate fisheries in waters which normally contain 25-80 mg/l suspended solids. Other factors being equal, however, the yield of fish from such waters might be somewhat lower than from those in category (1).
(3) Waters normally containing from 80-400 mg/l suspended solids are unlikely to support good freshwater fisheries, although fisheries may sometimes be found at the lower concentrations within this range.
(4) At the best, only poor fisheries are likely to be found in waters which normally contain more than 400 mg/l suspended solids." (NAS-NAE, 1972).

TABLE 14

Classification of suspended matter and their major impacts on freshwater ecosystems (Mulkey, 1977)

Type of Matter	Biochemical, chemical and physical effects	Biological Effects
natural inorganic material (clay, silt, sand)	Sedimentation, erosion and physical abrasion, turbidity (light penetration, habitat change)	Respiratory interference, habitat destruction, light limitation
natural organic matter	sedimentation, dissolved oxygen utilization	food sources, dissolved oxygen effects

The Illinois Pollution Control Board (IPCB) has not specified general use or public/food processing water supply standards for suspended solids. However, Rule 203(a) of Chapter 3 requires that waters not have unnatural sludge or bottom deposits, floating debris, visible oil, odor, unnatural plant or algal growth, unnatural color or turbidity, or matter in concentrations or combinations toxic or harmful to human, animal, plant or aquatic life of other than natural origin. Turbidity, caused by suspended silt, clay or other inorganic material (NVS) or by excessive plant or animal matter (TVS), can interfere with aquatic productivity by impeding light penetration and limiting photosynthesis. Excessive turbidity is aesthetically unpleasing and can be a nuisance. When plant life is diminished in quantity or quality (number of species) fish and other aquatic organisms are deprived of food, shelter and sites for reproduction.

Analytical determination of suspended solids by gravimetric methods has an accuracy of less than ± 2% for quantities in excess of 10 mg/l. Lower concentrations indue an increasing percentage error due to the accuracy of weighing and dehydration or absorption of water while weighing. The average accuracy of all suspended solids determinations should be ± 2%.

Concentrations of TSS were determined for each sample and averaged by water year, analysis period and station. These data are summarized in Table 15. Comparisons of averages and standard deviations for TSS shows the extreme variations in stations and anaysis periods.

The average concentrations of TSS decreased during both measurement periods (P1 and P2) for all stations. This decrease is related to increased surface cover and the low of rainfall that occurred P2. Mean water year TSS concentration by station ranged from 2892.60 mg/l at Station C to 13.20 mg/l at Station A. Mean water year TSS concentrations decreases from Station C to Station A.

The difference between mean TSS concentrations at Stations C and B results from the effects that the flow constricting structure at Station B has on streamflow. As streamflow is slowed, the solids settle out in pools or in the flood plain. The decrease in mean TSS concentration between the lake inflow and outflow results from dilution, sedimentation and decomposition of particulate matter. This is often referred to as the lake trapping efficiency it is expressed as a percent reduction. The trap efficiency of this lake is 93% (Lee, 1981).

The NAS-NAE suspended solids criteria would indicate that at Station A the fisheries potential would be excellent, the water at Station B would be unlikely to support good freshwater fisheries and only poor fisheries would be found at Station C. A fish population census was conducted on July 2, 1980 at Station C. Seven species of fish were collected, all of which are classified as tolerant to poor water quality. The creek chub was the predominant species, the complete results of the survey are listed in the Appendix Section.

TABLE 15

Average and standard deviations of total suspended solids concentrations for all stations by Water Year and analysis periods in milligrams per liter.

	Stations		
	A	B	C
Water year ($\overline{X}$) standard deviations	13.20 19.80	142.00 370.80	2892.60 7551.60
P_1 ($\overline{X}$) (May-June) standard deviations	17.70 28.20	217.60 566.10	4843.60 11745.00
P_2 ($\overline{X}$) (July-November) standard deviations	10.00 4.65	71.80 85.70	1317.10 2153.00

TABLE 16

Average and standard deviations of total volatile solid concentrations for all stations by Water Year and analysis periods in milligrams per liter.

	Stations		
	A	B	C
Water year ($\overline{X}$)	3.50	18.00	193.30
standard deviation	3.25	48.90	651.20
P_1 ($\overline{X}$)	4.78	26.60	242.40
standard deviation	3.95	74.70	481.40
P_2 ($\overline{X}$)	2.51	9.93	125.70
standard deviation	1.78	11.90	644.90

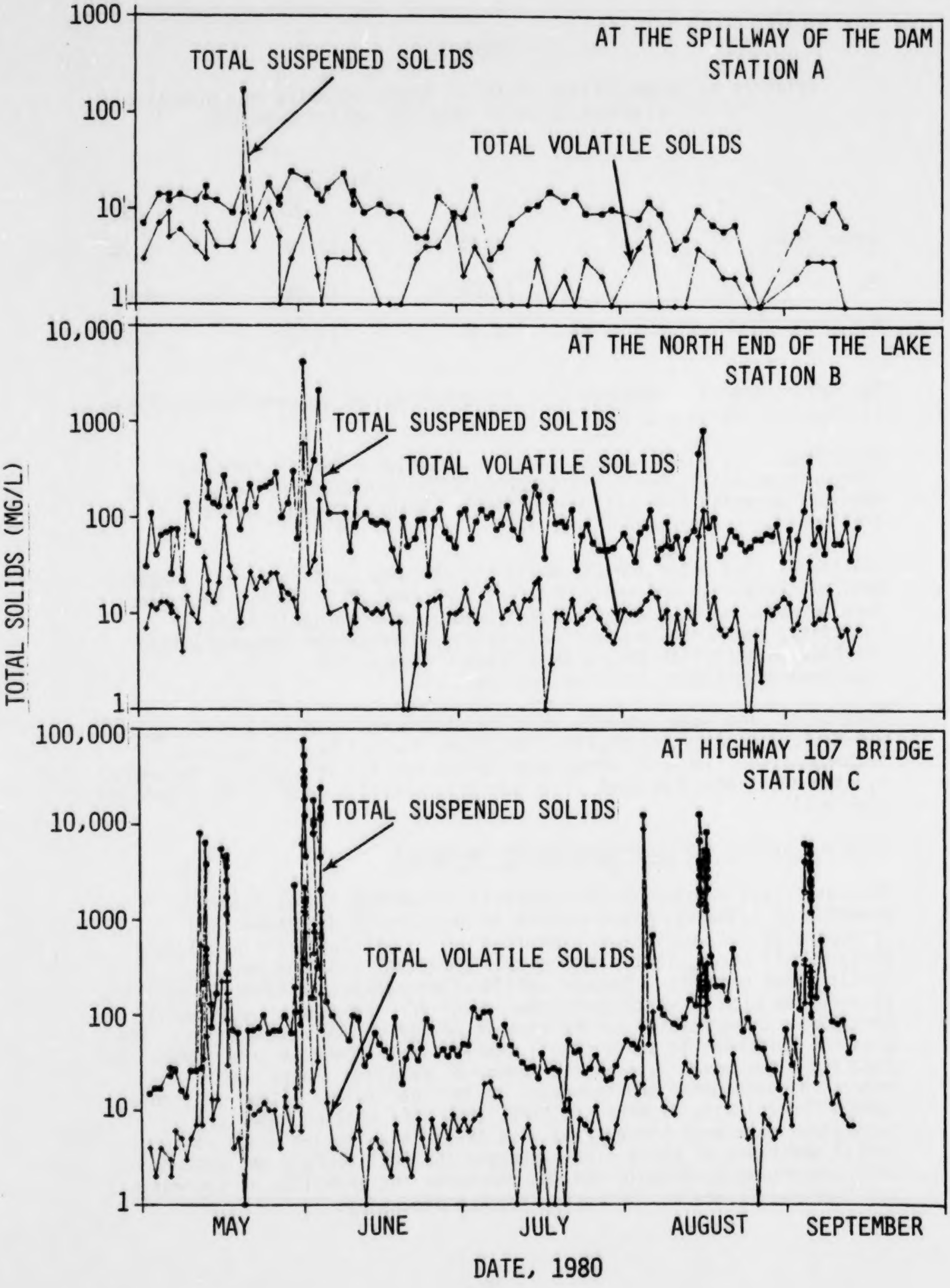
Concentrations of TVS were determined by water year, analysis period and station. These data are summarized in Table 16. Comparisons of averages and standard deviations for TVS shows the extreme variations in stations and analysis periods.

Mean Water Year TVS concentration exhibited a similar trend to TSS. The mean concentrations of TVS was lower for P_2 for all stations.

The TVS percentage of TSS ranged from 5.0% to 27.0% during P1 and 9.5% to 25.1% during P2 (Table 17). There is a distinct TVS "upstream -- downstream" trend with Station C have the lowest mean percentage of TSS as TVS and Station A the highest. TVS percentage of TSS increased between P1 and P2 at Stations B and C, it decreased at Station A. The increase at Stations B and C could result from foliage droppings in the stream and an increase in aquatic organisms.

TSS concentrations measured at Station A ranged from 1.0 mg/l to 170.0 mg/l; TVS ranged from 0.0 mg/l to 21.0 mg/l. Station B, TSS concentrations ranged from 22.0 mg/l to 41000.0 mg/l and TVS ranged from 0.0 mg/l to 580.0 mg/l. Station C, TSS ranged from 76000.0 mg/l to 4.0 mg/l and TVS ranged from 0.0 mg/l to 2250.0 mg/l (Figure 4). During periods of low flow there is a higher percentage of organic matter, compared with a higher percentage of mineral soil material in the higher runoff periods. Figure 1, shows the relative magnitude of suspended solids range by stations. Station C has the greatest range while Station A has the lowest. Peak and minimum TSS concentrations were higher during P1 than P2 for all three stations. Peak TVS concentrations were higher during P1 than P2 for all three stations, there was no difference between the P1 and P2 minimum values at any station.

Figure 7. Total Suspended Solids Concentrations over Time by Station. *



*Courtesy of ISWS

TABLE 17

Volatile solid percentage of total suspended solid concentration for all stations by Water Year and analysis periods.

	Stations A	Stations B	Stations C
Water Year	26.5%	12.7%	6.7%
P1	27.0%	12.2%	5.0%
P2	25.1%	13.8%	9.5%

The major impacts associated with suspended solids concentrations (Table 14) vary by stations and period of analysis.

Station C: The major impacts would be associated with the natural inorganic material; turbidity (reduced light penetration); erosion and physical abrasion (habitat destruction). Natural organic matter has a greater impact during P2 (Table 17).

Station B: The major impacts would be associated with natural inorganic materal; turbidity and sedimentation. Upstream of Station B the major impacts would be associated natural organic and inorganic matter; turbidity, sedimentation, and reduced dissolved oxygen concentration. THe flow constriction device at Station B causes this "upstream-downstream" difference in impacts.

Station A: The major impacts would be associated with natural inorganic material; turbidity and physical abrasion, natural organic matter; sedimentation. Table 17 shows over 25% of the TSS is organic, the water quality data indicates that dissolved oxygen utilization is not a problem (Table 14).

RAINFALL EVENTS AND SUSPENDED SOLIDS TRANSPORT

The basic soil erosion process converts the energy source from the momentum of raindrop impact to work in the form of detachment and transport of soil particles. Detached soil particles are flushed into surface soil pores, thus plugging soil pores and reducing soil infiltration capacity. Reduced infiltration results in higher quantities of overland flow at which point the energy for transportation of soil particles can be related to the kinetic energy of the moving water. The greatest deterrent to surface soil erosion is an adequate crop cover. An adequate plant cover absorbs the energy of raindrop impact thus preventing detachment and transport of soil particles. Stems and roots reduce the velocity of overland flow, thus infiltration rates are maintained at a much higher rate when there is an active plant cover. Annual additions of plant litter protect the soil surface and improve soil properties as organic residue increases the stability of aggregates and thus resistance to increasing erosion processes.

It is logical that those land management methods which expose maximum amounts of bare soil will have the larger amounts of soil loss. Agricultural land management which incorporates conservation tillage, contour planting and other best management practices has been effective in reducing soil loss.

Three periods, based on amount of surface cover were selected for evaluating rainfall and suspended solids transport: P1 (April-June); P2 (July-November); and P3 (December-March).

Streamflow and sediment transport are summarized for individual storm events which occurred during Water Year 1980 in Table 18. Several large storms which occurred during 1980 are not included, due to the lack of water quality information. The storms included in Table 18 are ranked according to total rainfall (inches), average streamflow (cubic feet/second), sediment concentration (milligrams/liter), and total suspended solids transported (tons/day).

Figures 8-13 are graphs of streamflow, total suspended solids and total volatile solids relationships for runoff events measured at Station C during the Water Year 1980. These runoff events occurred during P1 + P2 of the year. These figures show the variability in total suspended solids, total volatile solids, and streamflow concentrations.

A storm in June, 1981 produced a peak discharge of 442 cfs mid-morning on June 1 (Figure 8). The suspended solids concentration peaked prior to peak streamflow at 76,000 mg/l. This storm followed a two day period in which rainfall totaled 0.60 in. The extreme suspended solids concentrations on June 1 probably results from the two day previous rainfall detaching soil particles, and then infiltrating into the soil leaving the soil particles ready for transport. As the source area of runoff within the watershed expanded due to the extended period of preceeding precipitation, the potential source area of suspended solids expanded. The expansion of the perennial dimensions of the main stem enabled the flushing of available material within the entire channel network at one time, rather than temporal and spatial desposition of material occuring due to the lack of streamflow energy. The June 1st event provided the necessary energy for the transport of the available detached material. Cropland ground cover was minimal at this time. The streamflow records and personal observations confirm this.

Figure 8. Stream Flow, Total Suspended Solids and Total Volatile Solids Relationships for June 1, 1980 Storm Event

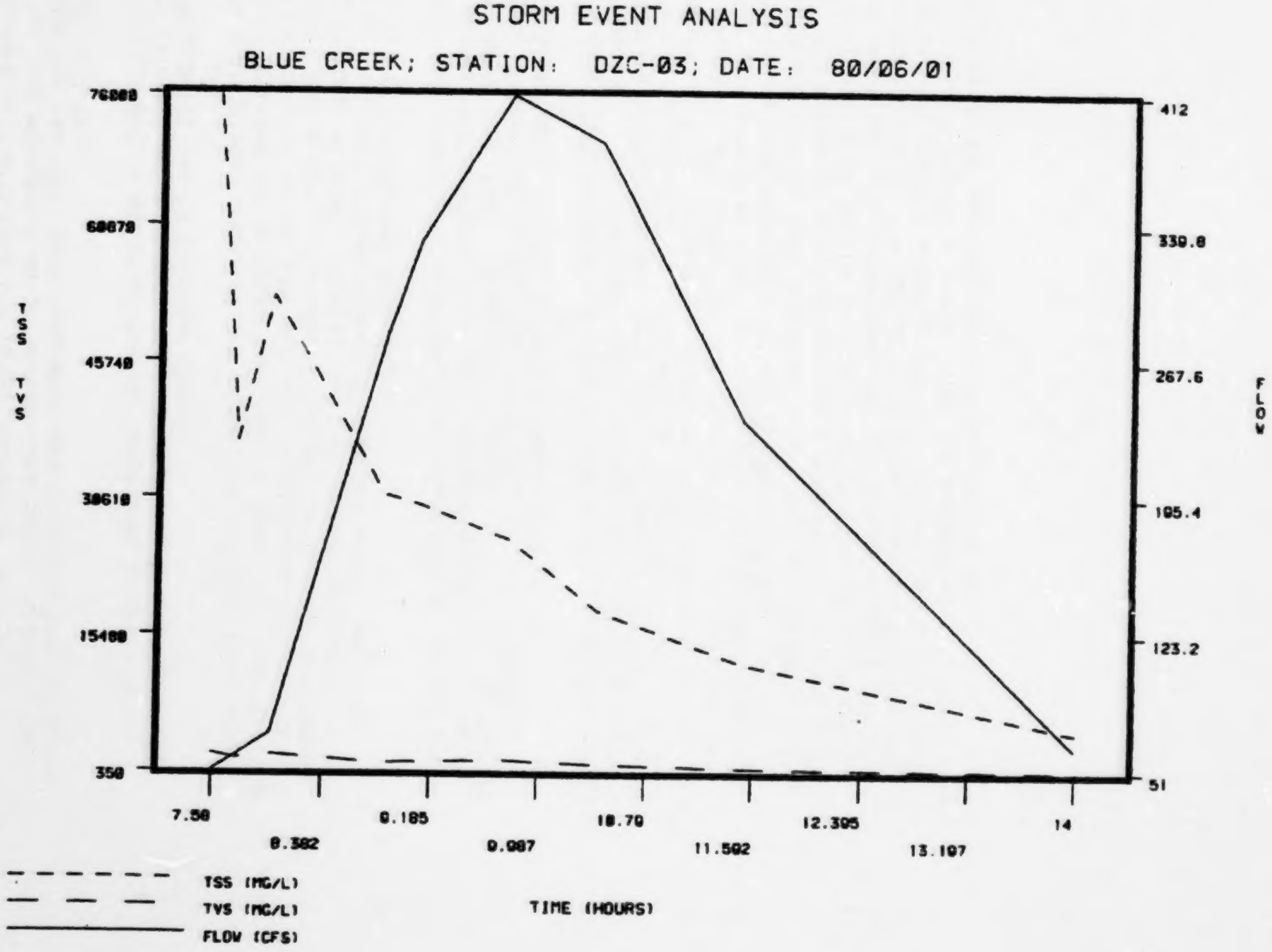


Figure 9. Stream Flow Total Suspended Solids and Total Volatile Solids Relationships for June 4, 1980 Storm Event

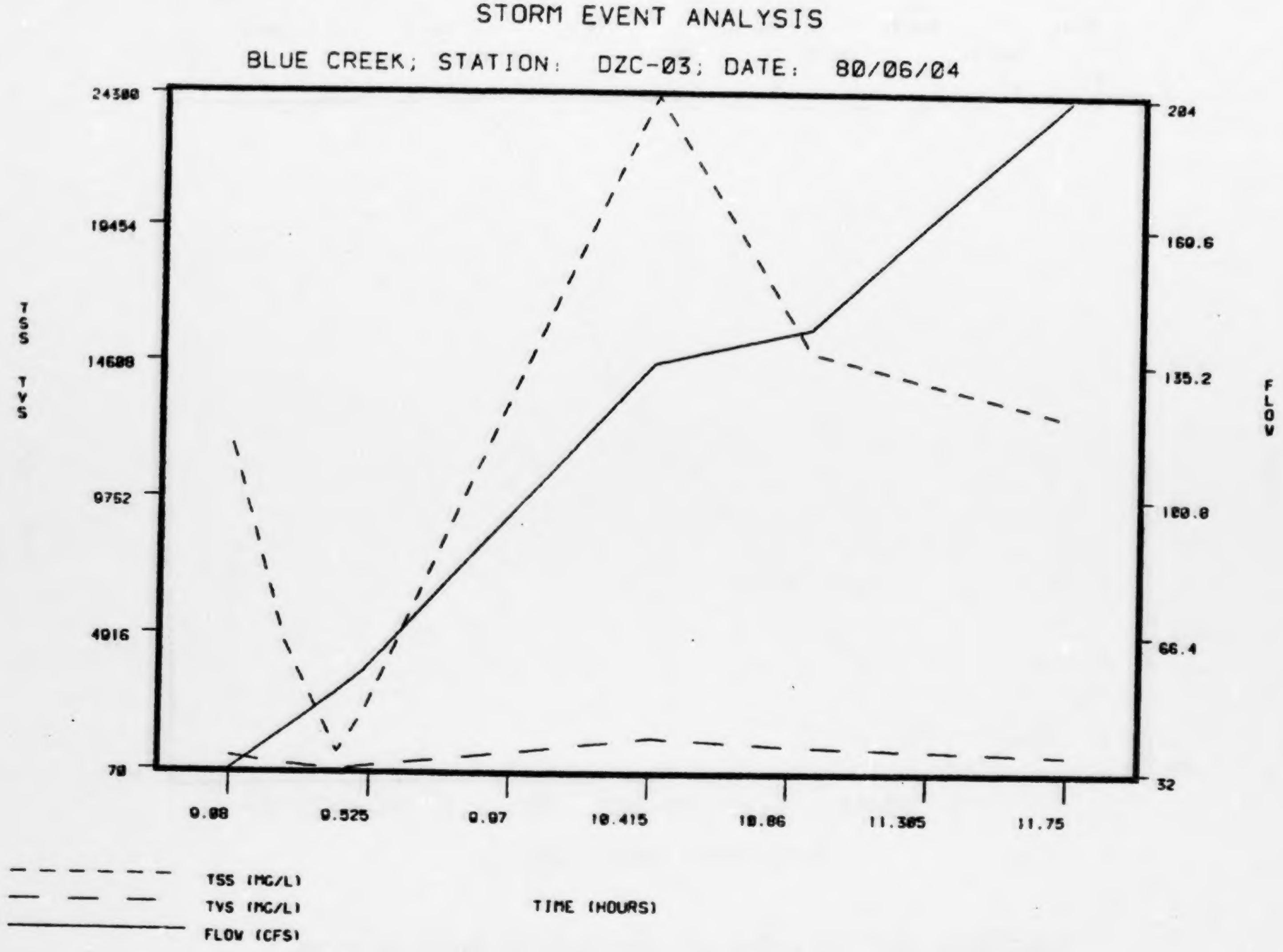


Figure 10. Stream Flow, Total Suspended Solids and Total Volatile Solids Relationships for August 15, 1980 Storm Event.

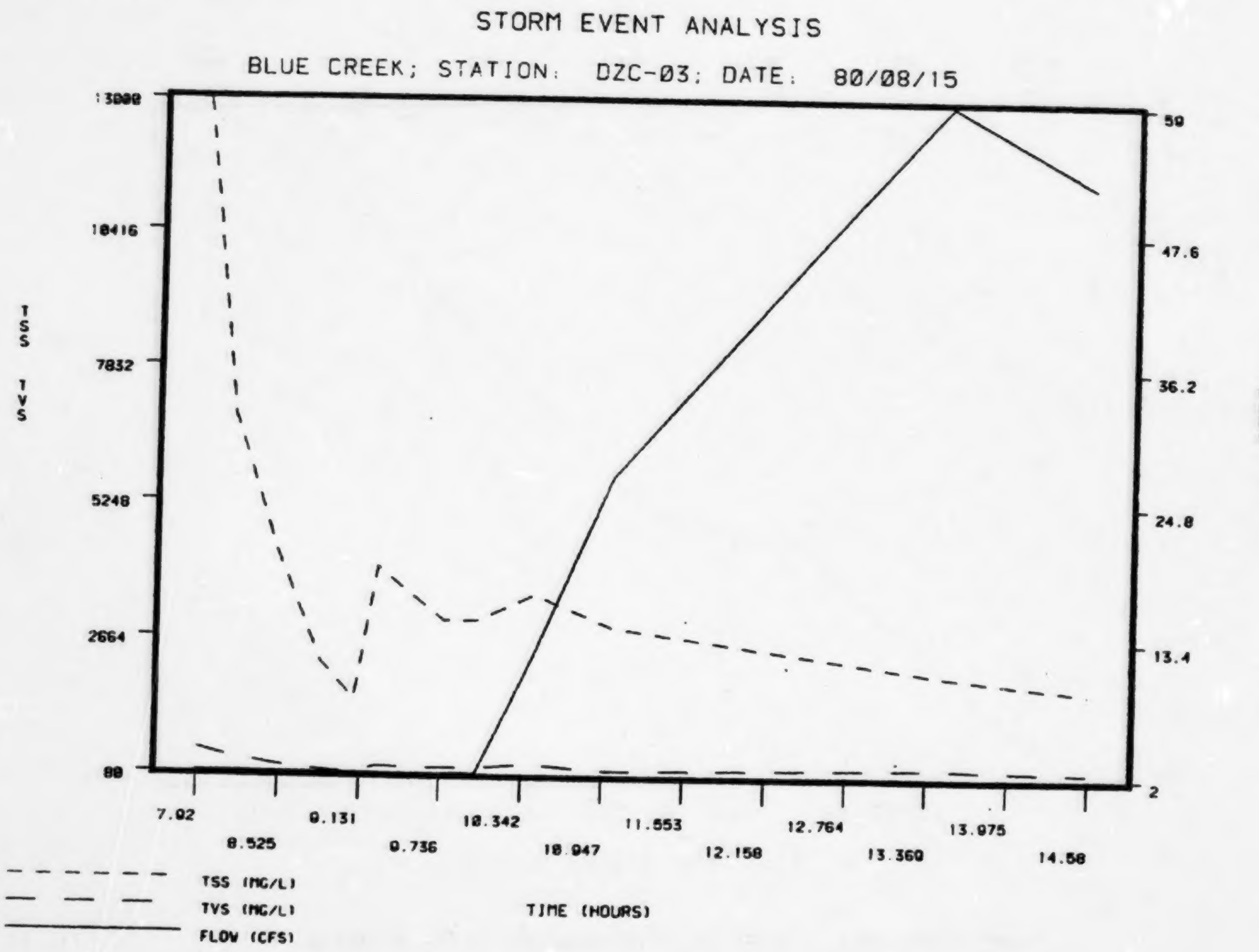


Figure 11. Stream Flow, Total Suspended Solids and Total Volatile Solids Relationships for August 16, 1980 Storm Event.

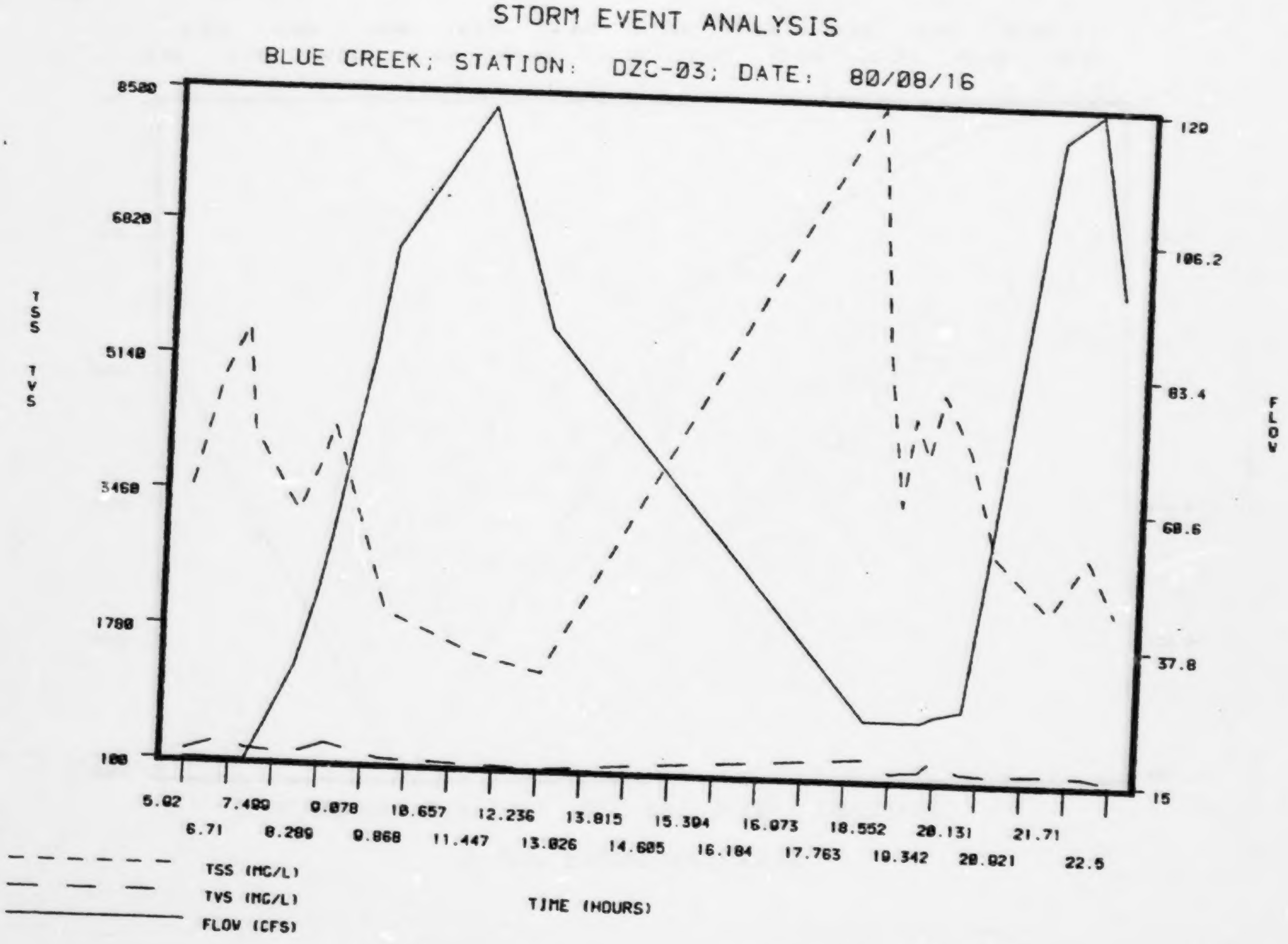


Figure 12. Stream Flow, Total Suspended Solids and Total Volatile Solids Relationships for September 5, 1980 Storm Event.

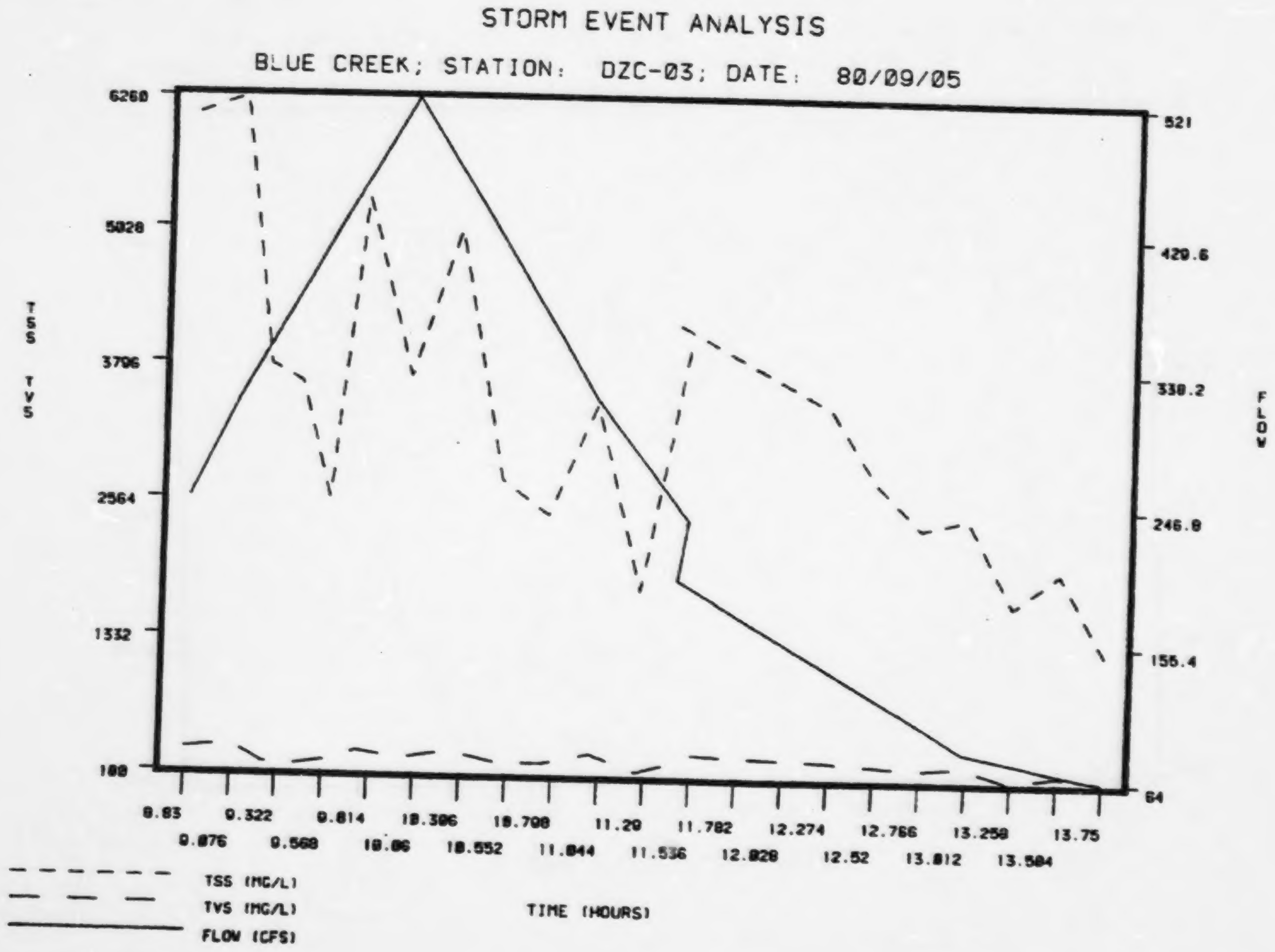
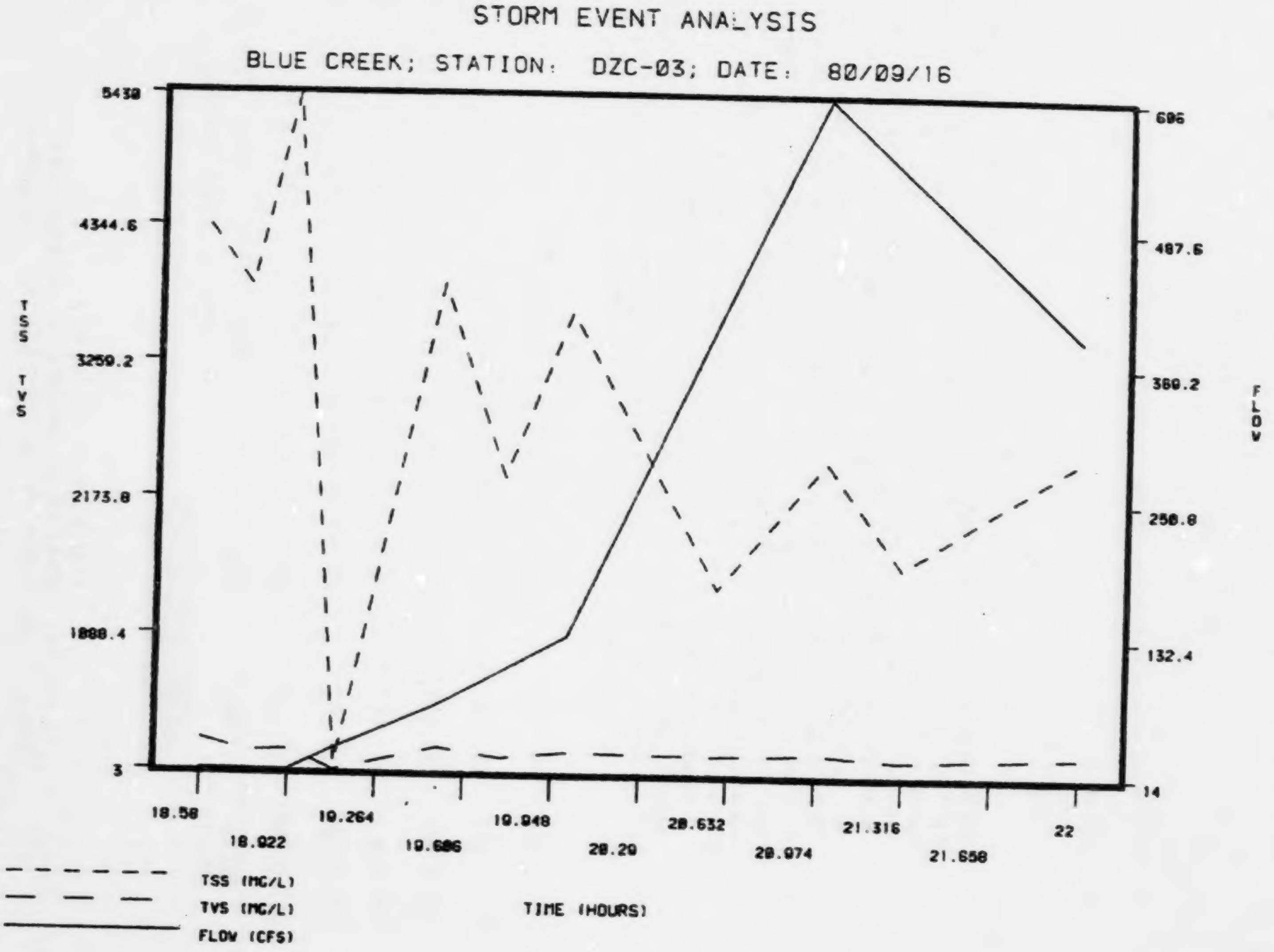


Figure 13. Stream Flow, Total Suspended Solids and Total Volatile Solids Relationships for September 16, 1980 Storm Event.



STORM EVENT ANALYSIS

BLUE CREEK; STATION: DZC-03; DATE: 80/09/16

TABLE 18

Streamflow, suspended solids concentrations and total suspended solid transported by event, Station C. Ranking in parenthesis.

Date	Precipitation (in)	Streamflow X (cfs)	Suspended Solids Concentration (mg/l) X	Max.	Min.	Load T/DAY
06/01	0.97 (4)	210 (3)	32,047 (1)	76,000 (1)	4,675 (1)	1052.0 (1)
06/04	0.64 (6)	95 (4)	10,142 (2)	24,300 (2)	710 (5)	285.0 (2)
08/15	1.19 (2)	14 (6)	4,000 (3)	13,000 (3)	1,500 (2)	8.8 (6)
08/16	0.96 (5)	54 (5)	3,746 (4)	8,500 (4)	1,300 (3)	79.1 (5)
09/05	1.33 (1)	246 (1)	3,384 (5)	6,260 (5)	1,260 (4)	193.0 (3)
09/16	1.17 (3)	212 (2)	2,665 (6)	5,430 (6)	59 (6)	140.0 (4)

Increased ground cover and below normal precipitation resulted in decreased total suspended solids concentrations during the remainder of the water year's runoff events. Canopy cover of fields in corn-soybean rotation was nearly 100% after July. 41% of the drainage area above Station C is in a type of corn-soybean rotation and 19% is in continuous corn (Davenport, 1982). The energy associated with the rainfall events in August and September may have been completely dissipated in the leaves of the crops. Soil detachment was reduced, thus compaction and sealing of the soil surface was reduced and infiltration is higher than during periods of less ground cover. The following comparison illustrates this. The June 1st event produced an average streamflow of 210 cfs, a maximum suspended solids concentration of 76,000 mg/l from 0.97 in. of total rainfall. The September 16th (Figure 13) event produced an average streamflow of 212 cfs, a maximum suspended solids concentration of 5,430 mg/l from 1.17 in. of total rainfall, only 7% of the peak concentration produced during the June 1st event.

Figures 8 and 9 shows suspended solid concentration peaking before peak streamflow. Two mechanisms cause this phenomenon. First; dilution thru a greater quantity of clear subsurface flow and interflow contributed to streamflow, this occurs following periods of soil saturation and increased infiltration. Second, decreasing availability of source material as the storm continues results in peak suspended solid concentration before peak streamflow. Following dry periods (July), material was detached by raindrop impact and carried directly into channels by overland flow, and material already in channels eroded by rising stage or deposited there from previous runoff events contributed to a rapid, early rise in suspended solids concentration. The rise in concentration is not maintained because the supply of most easily eroded and transportable materials is soon exhausted. Since canopy cover was nearly 100% during the August and September runoff events, the material transported was available either in close proximity or within the channel itself, peak suspended solids concentration decreased from 13,000 mg/l during the August 15th (Figure 10) event to 5,430 mg/l during the September 16th (Figure 13) event. Whereas average streamflow was 15 times greater during the September 16th event, so the available material for transport within the channel had not been replenished during this time period. August precipitation was mainly infiltrated into the soil, the streamflow records indicate this. A return to equilibrium conditions occurred over time as suspended solid concentrations and transport declined with ensuring rains because the supply of available material from soil erosion transportation and deposition within the channel diminished during August.

Suspended solid transport rates increased with continuing rain and increasing discharge but the peak concentration of suspended solids declined with increasing discharge. Initial early summer rains (June 1st & 4th) flushed the available supply of material propagated thru P1 activities, so that equally intense ensuing rains did not produce equal quantities of suspended solids transport, a process shown in Figure 8 and 13 and Table 18. A rainstorm of 28 hours produced 0.97 inches of total rainfall on June 1 resulting in peak suspended solids concentration of 76,000 mg/l. The maximum suspended solids concentration of 6,260 mg/l resulted from a 1.33 in. of rain in 5.4 hours on September 5 (Figure 12). The close dependence of suspended solids concentration on discharge should not be viewed as indicative of a transport capacity effect, because wash load is essentially a non capacity load, but rather that the erosion processes causing the suspended solids as would be indicated by the June 1st event when compared to the September 5th event.

Peak concentrations are reduced without dilution of tributary streamflow contribution, tributaries draining farmed uplands which sequentially join the main channel of Blue Creek carry more suspended solids than streamflow in the main channel (personal observation by Rod Mutz), due to deposition of larger particles and diffusion of peak concentration by differential velocities in the streamflow and storage of suspended materials in larger pools. Rodney Mutz's personal observation concerning the contribution of the upland areas was verified with a special rainfall runoff event sampling program, 3 samples were collected on June 4, 1980; 1 at the major tributary upstream from Station C, 1 at Station C and 1 upstream from the main tributary sampling; the suspended solids measured in mg/l were 4,570, 11,630, and 710 respectively. An attempt was made to sample the same section of stream flow by time lagging the sampling at the three locations. The tributary's concentration was greater than 6 times the main channel's concentrations.

Figures 8 and 12 show secondary peaks in suspended solids concentration during the runoff event. This results from upstream areas producing random pulse of material attributable to precipitation intensity, bank failure, release of an organic debris dam, channel erosion, and other natural occurances. The time lagging of flow from the upstream tributaries can produce the secondary peak concentrations at Station C.

Nutrients

Two problems are associated with nutrients in the aquatic environment: the water may be toxic to humans, animals, or fish when the concentration of certain nutrient forms exceeds a critical level; and euthrophication may be accelerated. Nitrogen, phosphorus, and potassium are essential nutrients for plant growth. Free floating aquatic vegetation, such as phytoplankton, depends on dissolved nitrogen and phosphorus compounds for its nutrient supply. Growth of these aquatic species may be limited by the availability of other nutrients. Dense algal growths sometimes occur in water resources that periodically receive increased concentrations of nutrients. These algal growths are generally undesirable and impair the use of the resource by people. The major sources of nutrients in streamflow are geochemical weathering, fertilizer and direct deposition from atmospheric sources. Nutrients from fertilizer can come from runoff of agricultural land or from groundwater return flow draining agricultural land. Nutrients also come from runoff and leachate from animal waste in livestock operations or from the animal waste disposal systems.

Phosphorus (P)

Phosphorus (P) is a key metabolic nutrient and the supply of this element often regulates the productivity of natural waters. In natural systems, P occurs as the orthophosphate anion (PO_4^{3-}) which may exist purely in organic forms (H_2PC_2- and HPO_4^{2-}) or be incorporated into an organic species (organic P). Under certain circumstances inorganic orthophate may exist as a poly or condensed phosphate. A secondary distinction is made between particulate and dissolved forms of P, the split conventionally being made at 0.45 um. Particulate matter is easily removed by filtration in the field with filtered samples analyzed for dissolved phosphorus (Ryden, et al, 1973).

P in its many forms in stream water originates from biological processes, geophysical erosion, commercial fertilizers, animal wastes, leachate and geochemical weathering of bedrock. Geophysical erosion is the process of physical breakdown of bedrock and smaller particles. Geochemical weathering dissolves and transports constituents to the streams. Rates are controlled by characteristics of climate, soils, topography, biotic agents and bedrock formations (Fredricksen, 1979). TP from commercial fertilizers and animal waste enters the stream ecosystem from leaching and perolcation thru the soil matrix.

The Illinois Pollution Control Board (1977) has established a general use standard of 0.05 mg/l for TP in any lake or stream at the point where it enters a lake. A general index of maximum desirable concentrations is as follows; 0.10 mg/l in flowing, 0.05 mg/l for streams flowing into lakes and reservoirs, and 0.025 mg/l in lakes and reservoirs (U.S. Environmental Protection Agency, 1976).

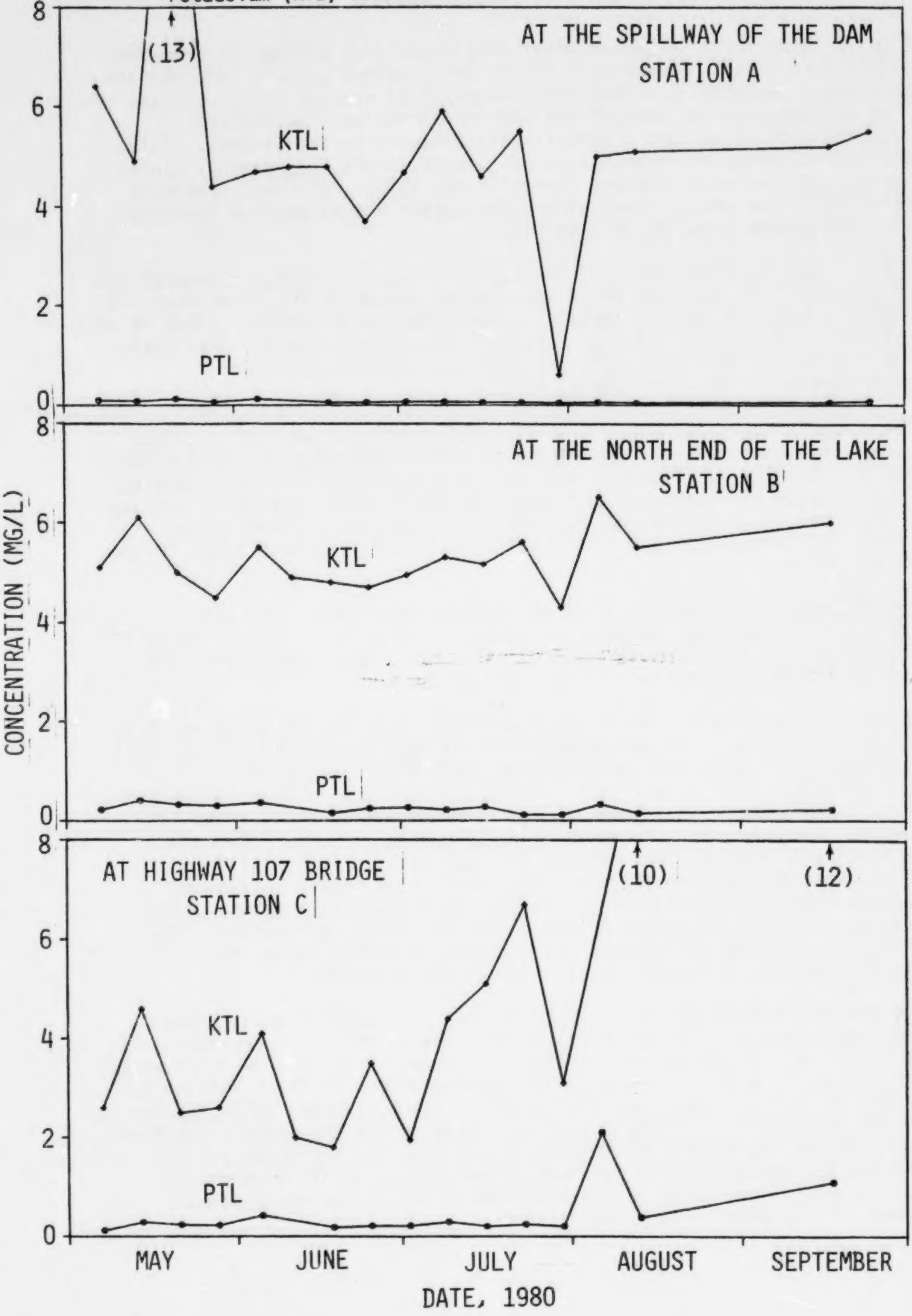
The overall, short-term impact of surface runoff derived P on standing waters is expected to be high because a large proportion of the average annual discharge of TP occurs over only short periods of time during the annual cycle. Furthermore, the impact of the TP load carried in streams is expected to be greater during late spring and early summer when aquatic microorganisms are in the potentially active growth phase (Ryden, et al, 1973).

The average concentrations of TP by station, water year, and the individual measurement periods are shown in Table 19. Figure 4 shows TP concentrations over time by station. The individual observations are listed in the data section of the Appendix Section.

In general, Station C's P1 TP concentrations were approximately equal to P2 concentrations. The two exceptions; 2.1 mg/l (August 6) and 1.1 mg/l (September 17) which were measurements taken after periods of low-intensity soaking rainfalls. These rainfall events followed extended dry periods between low-runoff-volume rainfall events in July and late August. Kennedy (1971) found increase in solute concentration with increasing time of contact between soil and water. Newly infiltrated rain displaces and mixes with residual soil water that has been in contact with soil during the dry period, then percolates to the stream course, resulting in higher TP concentrations in the streamflow. The amount of time the infiltrated rain remains in contact with the soil depends upon the antecedent soil moisture concentration.

The average concentrations of total TP decreased significantly between the measurement periods (P1 & P2) at Stations A and B. TP decreased 86% during P1 and 75% during P2. Average TP, measured at Station B decreased 31% between P1 and P2. The elevated concentrations of TP at Station B during P1, could result from the fertilization activities being carried out in the watershed, high streamflow during spring may scour algae from rocks in the stream thus minimizing consumption and the release of TP from bottom sediment. The two peak concentrations of TP measured at Station C were not found at Stations A or B due to the instantaneous nature of the water quality conditions.

Figure 14. Total Phosphorus (PTL) and Potassium (KTL) Concentrations Over Time by Station.*



*Courtesy of ISWS

TABLE 19

Average and standard deviations of Total Phosphorus concentrations for all stations by Water Year and analysis periods in milligrams per liter

	Stations A	 B	 C
Water year ($\bar{X}$)	0.06	0.23	0.43
standard deviations	0.03	0.09	0.47
P_1 ($\bar{X}$) (May-June)	0.08	0.28	0.23
standard deviations	0.03	0.09	0.10
P_2 ($\bar{X}$) (July-November)	0.05	0.20	0.54
standard deviations	0.01	0.07	0.65

Decreases in TP concentrations from the upstream Station C and B to the lake outflow Station (A) is due to a number of factors: 1) dilution, 2) biological uptake and 3) absorption and/or adsorption by chemically active material. Adsorptions of P on clay minerals involve at least two mechanisms -- Vander Wal forces of attraction and isomorphic substitution of P for silicate in the clay structure. Phosphate anions are removed from water by kaolinite and montmorillanite (Van Olphen, 1963). P, bounded tightly to soil particles, is removed from suspension as sediment (Lin, 1972). Sediment may act as reservoirs of TP in natural systems (Stumm, 1970). Adsorption or reaction of TP with bases and metals (Hen, 1975) is the major reason for reduced concentrations in the soil solution (groundwater) and streams. Rapid utilization of TP, in the form of PO_4-P, by aquatic vegetation also occurs in flowing streams and lakes (Wetzel, 1975). There is a change in land use/cover composition between Stations B and C. The management pattern in this area (refer Figure 2) is distinctly more conservation oriented than that area draining to Station C. This change in management pattern can be associated with less TP available for input into the aquatic system. The combination of these phenomenons cause this decrease.

The decreases in TP concentrations between the lake inflow and outflow stations result from dilution, biological uptake and fixation by sediment. TP concentration measured at lake site 2 is lower than that measured at Station B, whereas lake site 1 values are equivalent to those at Station A. However, Ryden (1973), asserts a major unknown factor centers around the effects of mixing as streams enter standing waters. He suggests that temperature density and turbulence differences between stream water and standing water will have some effect on the degree of mixing. The degree of mixing influences the degree that dilution, biological uptake and fixation by sediment impact upon TP concentration in the water column.

Nitrogen (N)

Most of the nitrogen (N) in a stream has a terrestrial origin. Major sources of N are atmospheric deposition, biological fixation, fertilizers, and leachate from animal wastes. The forms of N in water include dissolved molecular N proteins and amino acids), ammonia, nitrate (NO_3), and nitrite (NO_2). Loss of N to streams seems to be regulated primarily by biological processes (Likens, 1977) and geochemical reactions in parent material and bedrock (Fredriksen, 1979). Stored N in the soil is utilized by vegetation and returned partly to the soil as litter fall when plants die. Organic N is unavailable for immediate plant use, it is mineralized to more available forms (NH_4-N, NO_3-N) by biological activity.

Sediment can be a source of N to the aquatic environment. Suspended solids in streamflow may have adsorbed or complexed with forms of N either organic or inorganic compounds. Clay minerals and amorphous material, fine grain sediments, have chemically active surfaces which adsorb N compounds (Loughnan, 1969). Legumes, can fix large amounts of N in the soil which can subsequently leached into surrounding waters.

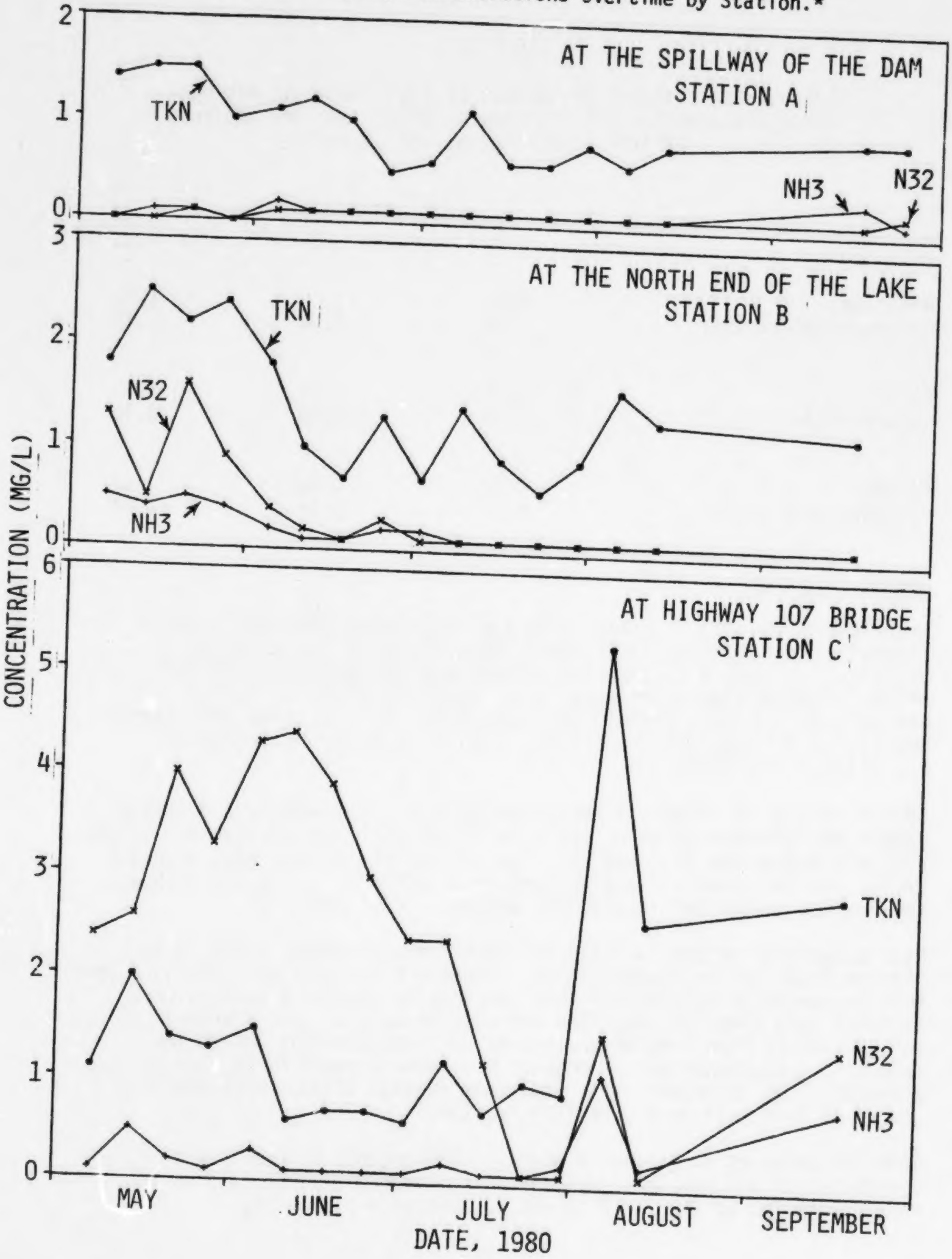
Total Kjeldahl Nitrogen (TKN)

Analysis for total Kjeldahl nitrogen (TKN) measures both ammonia and organic nitrogen. TKN minus ammonia nitrogen is equivalent to the organic N level. Both of these forms occur in organic detritus resulting from natural biological activity. Since ammonia and organic N are both possible contributors to the nutrients pool, their quantification is important in assessing the amount of nitrogen available for biological activities (Sefton, 1980).

Concentrations of TKN were determined for each weekly streamflow sample and averaged by Water Year, period of analysis and station. Figure 15 shows TKN concentrations over time by station. These data are summarized in Table 20. Comparisons of averages with standard deviations for TKN shows the extreme variations in stations and periods of analysis.

Mean Water Year TKN concentrations by station ranged from 1.51 mg/l at Station C to 0.95 mg/l at Station A. Laterally, mean Water Year TKN decreases from Station C to Station A. Station A's TKN concentration is higher than lake site 1 (Table 35), this increase results from organic matter contribution from the land area surrounding Station A.

Figure 15. Total Kjeldahl Nitrogen (TKN), Nitrate-Nitrite (N32), and Ammonia (NH3) Concentrations Overtime by Station.*



*Courtesy of ISWS

TABLE 20

Average and standard deviations of Total Kjeldahl Nitrogen concentrations for all stations by Water Year and analysis periods in milligrams per liter.

	Stations		
	A	B	C
Water year ($\overline{X}$)	0.90	1.36	1.74
standard deviations	0.31	0.54	1.25
P1 ($\overline{X}$)	1.15	1.71	1.16
standard deviations	0.33	0.66	0.48
P2 ($\overline{X}$)	0.77	1.10	1.82
standard deviations	0.18	0.34	1.54

Organic Nitrogen

Organic nitrogen (N) is unavailable for immediate plant use, it is mineralized to more available forms (NH_7-N, NO_3-N) by biological activity. Organic N is primarily formed and degraded by biological action. Common species of organic nitrogen are proteins, protein derivatives, perines, pryimidines, and urea. Some of these are readily degradable and some are not. Farm runoff is a source of organic N (Willrich et al. 1970).

Concentrations of organic N were calculated for each weekly streamflow sample and averaged by water year, period of analysis and station. These data are summarized in Table 20. Comparisons of averages with standard deviations for organic N and percentage of TKN that is organic N shows the extreme variations in stations and periods of analysis.

Mean Water Year values indicate an "upstream-downstream" trend, with Station C having the highest value. Organic N decrease thru the lake and then increases at Station A. This increase at Station A results from littoral zone contribution. The decrease in mean organic N between P1 and P2 results from lack of organic matter contributions due to low rainfall, transformations of organic N to more useable forms, and by the permanent loss of organic N to sediments (Wetzel 1975), which serve as a source of N as well as a sink (Austin, 1973).

Mean TKN measured at Station C averaged 83% organic N, the lowest percentage of all sampling stations. The organic N percentage of TKN ranged from 78% at Station B to 96% at Station A (Table 21).

TABLE 21

Average and standard deviation of Organic Nitrogen concentrations for all stations by Water Year and analysis period in milligrams per liter. Organic Nitrogen is defined as the difference between Total Kjeldahl Nitrogen and Ammonia Nitrogen. Percentage of Total Kjeldahl Nitrogen as Organic Nitrogen.

	Stations A	 B	 C
Water year ($\overline{X}$)	0.91	1.23	1.27
Standard deviation	0.32	0.42	0.92
Percentage of Total Kjeldahl N	94%	85%	83%
P1 ($\overline{X}$) (May-June)	1.11	1.42	0.97
Standard deviation	0.33	0.46	0.37
Percentage of total Kjeldahl N	96%	78%	84%
P2 ($\overline{X}$) (July-November)	0.73	1.04	1.52
Standard deviation	0.17	0.35	1.19
Percentage of total Kjeldahl N	93%	94%	83%

Nitrates-Nitrites(NO_3 & NO_2-N)

Fertilizers, biological fixation, mineralizations and nitrification input nitrate (NO3-N) into the aquatic system. Denitrification, plant uptake, immobilization by soil organic matter and leaching are processes by which NO_3-N leaves the system. NO_3-N lost from the terrestrial system through soil leaching is the dominant source observed in stream water.

Specific agricultural activities associated with NO_3-N are disposal of animal waste and fertilization. Anhydrous ammonia and urea are the principal forms of commercial fertilizer applied presently. Animal manure is a principal form of fertilizer within this watershed due to large livestock operations. All three of these fertilizers are a source of nitrate, because the breakdown of anhydrous ammonia, urea, and animal manure to NO_3-N.

Concentrations of NO_3 & NO_2-N were determined for each weekly streamflow sample and averaged by water year, period of analysis and by station. These data are summarized in Table 22. Figure 15 shows NO_3+NO_2-N concentrations over time by station. Comparisons of averages with standard deviations of nitrate-nitrite shows the extreme variations in stations and periods of analysis.

There was significant differences between NO_3 & NO_2-N concentrations during P1 and P2 at Stations B and C. Available NO_3 & NO_2-N increases during P1 (Spring) due to the mineralization of organic N and inputs from fertilizer. This NO_3 & NO_2-N is free to move with the soil water. This flow enters the stream course by percolation (subsurface flow). Consumption by crops during P2 (summer) reduces available NO_3 & NO_2-N for soil water transport, thus reducing the concentration in streamflow. NO_3 & NO_2-N concentrations in soil are nearly exhausted about the time of corn senescence (Langdale, 1978). There was no signficiant difference between NO_3 & NO_2-N concentrations during P1 and P2 at Station A. Samples collected at this station reflects Pittsfield City Lake outflow and the littoral zone of the lake.

There is a significant difference between NO_3 & NO_2-N concentrations at stations B and A. The decrease in mean NO_3 & NO_2-N concentration between the lake inflow and outflow stations results from dilution, and biological uptake. NO_3 is assimilated by algae and larger hydrophytes and reduced to ammonia. The assimilation of NO_3-N and its reduction by green plants is of major proportions in the trophorgenic zone of lakes. Decreases in mean NO_3 & NO_2-N concentration between stations C and B result from plant consumption and dilution. Mean NO_3 & NO_2-N concentrations did not exceed the limits determined by Knepp (1973) and Mccoy (1972) for adversely affecting warmwater fish. The limits are: NO_3-N 90 ppm or less and NO_2-N is 5 ppm or less.

TABLE 22

Average and standard deviations of Nitrate-Nitrite concentrations for all stations by Water Year and analysis periods in milligrams per liter.

	Stations		
	A	B	C
Water year ($\overline{X}$)	0.02	0.32	1.85
standard deviations	0.06	0.49	1.41
P1 ($\overline{X}$) (May-June)	0.01	0.65	3.19
standard deviations	0.04	0.56	1.39
P2 ($\overline{X}$) (July-November)	0.03	0.03	1.09
standard deviations	0.07	0.05	0.96

Ammonia (NH_3-N)

Ammonia is the most reduced inorganic form of N in water. Analysis of water samples normally includes ionized ammonia (ammonium NH_4+) and unionized ammonia (NH_3) with results expressed as total ammonia N. N fixing organisms (algae, bacteria etc.) living in symbiotic association with plants in soil or water reduce (elemental) N to NH_3-N and the NH_4-N ion.

NH_3-N is a highly soluble compound resulting from either the decomposition of nitrogenous organic matter (plant or animal wastes) or the microbial reduction of NO_3-N or NO_2-N under anaerobic conditions. NH_3-N associated with clay minerals enters the aquatic environment through soil erosion. Soils containing large amounts of vermiculitic or illitic type minerals have the capacity for fixing NH_3-N (Willrich, 1970). Commercial fertilizers to improve crop yields contain highly soluble HN_3-N and HN_4-N salts. When the concentration of such compounds exceed the immediate plant requirements, precipitation or irrigation waters carry these nitrogen compounds into the aquatic system (McNeely, 1979). The animal wastes from feedlots and in other areas of contaminant can act as sources of NH_3-N in surface wastes.

NH_3-N is a non-persistent, non-cumulative toxic substance and in low concentrations present no physiological detriment to man or livestock. Fish cannot tolerate large quantities of NH_3-N since it reduces the oxygen carrying capacity of blood and thus the fish may suffocate (McNeely, 1979). For general use waters, the Illinois Pollution Control Board (1977) specified that NH_3-N should not exceed 1.5 mg/l, while USEPA has recommended setting a limit of 0.02 mg/l on the unionized form (NH_3) for protection of aquatic life.

NH_3-N concentrations did not exceed the 1.5 mg/l limit established by the Illinois Pollution Control Board, only one sample exceeded, 1.0 mg/l. However, NH_3-N concentrations at all three stations frequently exceeded the 0.02 mg/l limit that USEPA recommended (Appendix Section).

TABLE 23

Average and standard deviations of Ammonia concentrations for all stations by Water Year and analysis periods in milligrams per liter.

	Stations A	Stations B	Stations C
Water year ($\overline{X}$)	0.04	0.18	0.37
standard deviations	0.09	0.18	0.51
P1 ($\overline{X}$)	0.04	0.29	0.19
standard deviations	0.07	0.19	0.14
P2 ($\overline{X}$)	0.04	0.06	0.30
standard deviations	0.10	0.07	0.38

Comparisons of averages with standard deviations for NH_3-N shows the extreme variations in stations and periods of analysis (Table 23). Figure 15 shows NH_3-N concentrations over time by station. NH_3-N concentration trends resemble those NO_3 + NO_2-N at Stations A and B (Table 20, Figure 15). Biological conversion, subsurface contributions, and NH_3-N released into the stream through decomposition of organic debris possibly explain the increase in mean NH_3-N concentration during P2 at Station C.

NH_3-N concentrations trends measured at Station C resemble those of TP (Table 18) measured at Station C (Figure 14). The interrelationship of Kennedy's (1972) concept of relative time and Wallings (1975) concept of subsurface flushing explain the higher NH_3-N concentrations measured after the August 6 and September 17 rainfall events. The rainfall events followed extended dry periods between low-runoff-volume rainfall events in July and August. Most of the rainfall during this period was infiltrated into the soil. The newly infiltrated rain displaces and mixes with residual soil water that has been in contact with soil during the dry period, this percolates to the stream course, resulting in higher NH_3-N concentrations in the streamflow. This contribution occurs, thru the baseflow component, during the receding streamflow level of rainfall induced runoff. This agrees with Weart and Musgrave (1957) findings of NH_3-N in a number of Illinois groundwater wells.

The reducing environment and assimilation of NO_3-N by biological organisms explains the increase of mean NH_3-N concentration from Station C to B. Large quantities of sediment and organic matter have settled out at Station B due to the flow constricting structure located there. The relationship of NH_3-N concentrations between Stations B and A resembles that of NO_3 + NO_2-N (Table 22) due to similar reasons.

Potassium (K)

Potassium (K) is an essential element for plant and animal nutrition. Most soils are lacking in adequate amounts of available K. K is an alkali metal. In response to weathering after leaching, K usually is incorporated into new stable minerals (clay). K is a principal component of some fertilizers.

K is a monovalent cation involved primarily in ion transport and exchange.

The concentration of K in natural surface water seldom reaches 20 mg/l and is generally less than 10 mg/l (McNeely, 1979). The rather narrow range of concentration of K observed in natural water suggests a significant chemical control mechanism may be involved (Hem, 1979). K usually is not connected with water pollution.

K concentrations show the greatest variation at Stations A and C, ranging from 0.6 to 13 mg/l and 1.8 to 10.0 mg/l, respectively. Peak K concentrations corresponds to periods of high streamflow after storm events (Figure 15). Whereas the least variation was measured at Station B (4.3 to 6.5 mg/l). The narrow range of concentration at Station B could result from the effects of the flow constriction structure stabilizing lake inflow and the potential chemical interactions with the bottom sediments. Figure 15 shows K concentrations over time by station.

In comparison, K concentration measured at Station B and C increases during P2, at Station A there was not a significant difference. Laterally, between Stations, there was not a signficant difference in K concentrations (Table 22).

Evaluated K concentration after rainfall runoff events would indicate groundwater flushing or high interflow contributions to streamflow, if the K ions were not complexed.

TABLE 24

Average and standard deviations of Potassium concentrations for all stations by Water Year and analysis periods in milligrams per liter.

	Stations		
	A	B	C
Water year ($\overline{X}$)	5.04	5.13	4.29
standard deviations	2.14	0.59	2.48
P_1 ($\overline{X}$)	5.84	5.08	2.96
standard deviations	2.99	0.51	1.00
P_2 ($\overline{X}$)	4.68	5.42	5.46
standard deviations	1.58	0.62	2.85

Heavy Metals Trace Elements and Pesticides

While most trace elements occur naturally in the environment, extensive use of metals in industry often results in concentrations greatly exceeding natural levels. Certain heavy metals are known to be highly toxic to aquatic organisms and cumulative in the food chain (Hesse, 1972). Because accumulation of heavy metals may result in complex changes in the structure and stability of aquatic ecosystems (McFarlane, 1978) a multitude of studies have been conducted to document metal accumulation in aquatic environment (Hesse, 1972; Kleinert et al. 1974; and Matlus 1971) (Sefton, 1980). All heavy metals and related trace elements were anayzed monthly at Stations A, B and C; except iron which was analyzed as part of the weekly water quality sampling program.

No preliminary trend analysis was attempted due to the low number of observations. Table 25 summarize the data for Water Year 1980 by station. Treflan, Dieldrin, Atrazine and Lasso were the only pesticide compounds in measurable quantities. All data is listed in the Appendix Section.

TABLE 25

Means and number of observation above detectable heavy metals and trace elements by station.

	Station A	Station B	Station C
CALC (mg/l)	28.3 (4)	35.0 (4)	60.8 (4)
MAGN (mg/l)	13.6 (4)	16.9 (4)	30.0 (4)
SODI (mg/l)	5.0 (4)	6.7 (4)	9.5 (4)
BARM (ug/l)	67.8 (4)	91.2 (4)	180.0 (4)
BOR N (ug/l)	19.0 (1)	18.0 (1)	23.0 (1)
COPR (ug/l)	10.0 (1)	10.0 (1)	11.02 (2)
IRON (ug/l)	205.0 (4)	1132.5 (4)	1170.0 (4)
MANE (ug/l)	46.8 (4)	300.0 (4)	837.5 (1)
STRN (ug/l)	64.3 (4)	72.5 (4)	121.3 (4)
ZINC (ug/l)	10.0 (1)	16.0 (2)	32.0 (2)
LITH (ug/l)	150.0 (1)	200.0 (1)	250.0 (1)
BERL (ug/l)	0	1.0 (1)	0
CHRM (ug/l)	0	17.0 (1)	10.0 (1)
VAND (ug/l)	0	11.0 (2)	120.0 (1)
CADM (ug/l)	0	0	0
CBLT (ug/l)	0	0	0
SIL (ug/l)	0	0	0
LEAD (ug/l)	0	0	0
MERC (ug/l)			
NICKL (ug/l)	0	0	10.0 (1)

Organic Matter Demand

Organic matter in natural waters includes a great variety of organic compounds. Collective parameters, such as chemical oxygen demand (COD) and biological oxygen demand (BOD) are used to estimate the total quantity of organic matter present.

BOD is a measure of the amount of oxygen required by microorganisms to decompose the organic matter in a water sample under a specific set of conditions. COD is a measure of the total amount of oxygen which is required to completely oxidize all of the organic matter in a sample to carbon dioxide and water.

The COD of water increases with increasing organic matter concentrations COD may also be used to estimate BOD. COD exceeds the BOD of water due to inability of aerobic bacteria to completely oxidize the more resistant organic constituents under the conditions of the BOD test.

In addition to oxygen depletion and resulting changes in aquatic life, decomposing organic matter contributes or causes color, taste, and odor problems in surface water. Such problems are difficult to solve, yet their impact upon people are highly significant.

BOD is not a pollutant itself, but it is a measure of organic pollution. A BOD load can pose a threat to the aquatic environment by depressing the dissolved oxygen concentrations to levels that affect aquatic organisms. BOD levels less than 4.0 mg/l are deemed reasonably clean waters. Waters with levels greater than 10.0 mg/l thus are considered polluted since they contain large amounts of degradable organic matter (McNelly, 1979).

It seems fairly self evident that the oxygen demand of the dissolved and particulate organic matter accounts in large measure for oxygen concentrations of less than 100 percent saturation. The BOD level measured at Stations A & B during Water Year 1980 did not exceed 10 mg/l. BOD levels exceeded 10 mg/l on two occasions at Stations C, both times were after periods of intense, large runoff producing storm events. Mean BOD levels decreased significantly from P1 to P2 (Table 26 at Stations A & B). This is probably due to the low rainfall. The BOD data is listed in the Appendix Section.

TABLE 26

Average and standard deviations of BOD for all stations by Water Year and analysis periods in milligrams per liter.

	Stations		
	A	B	C
Water year ($\overline{X}$)	5.05	9.32	7.05
standard deviations	2.91	11.90	4.85
P1 ($\overline{X}$) (May-June)	6.57	6.06	4.14
standard deviations	2.76	2.24	1.21
P2 ($\overline{X}$) (July-November)	3.77	4.78	6.44
standard deviations	1.39	1.99	4.77

COD may reduce dissolved oxygen levels, thus affecting the survival of aquatic organisms, but no water quality guidelines for COD have been proposed. Comparisons of averages with standard deviations for COD shows the extreme variations in stations and periods of analysis (Table 27) Station C values had the most variation ranging from 11.0 to 121.0 mg/1. Whereas the variation at Stations A and B ranged only 13.0 and 17.0 mg/1, respectively. The peak value at Station C 121.0 mg/1 was measured after intense rainfall event. There is a significant decrease in COD values from Station B to A, this results from natural limonological process occurring in the lake. The COD data is listed in the Appendix Section. COD values are significantly higher than BOD values due to the testing procedure.

TABLE 27

Average and standard deviations of COD for all stations by Water Year and analysis periods in milligrams per liter.

		Stations	
	A	B	C
Water year ($\overline{X}$)	21.18	26.53	29.41
standard deviations	3.57	4.46	28.19
P1 ($\overline{X}$)	22.00	27.50	18.63
standard deviations	4.54	4.28	9.97
P2 ($\overline{X}$)	20.44	25.67	39.00
standard deviations	2.51	4.69	35.81

Fecal

Fecal coliform (FC) and strep (FS) are being measured at Stations A, B and C within the watershed. The ratio $\frac{FC}{FS}$ will be used to determine if pollution is from human or animal feces.

FC bacteria, although not harmful in themselves, indicate that a potential hazard to human health exists. Water with FC bacteria may contain fecal matter that can transmit disease caused by bacteria and viruses.

FC: FS ratio of 4.0 or higher typically indicate human wastes while ratios of 0.6 or lower are common to discharges associated with farm animals (APHA, 1980). Ratios between 4.0 and 0.6 indicate mixed sources of fecal matter.

Table 28 shows the average and standard deviations of fecal coliform and strep by station, by water year and individual measurement periods. Mean FC concentration exceeded the 200/100 ml level set by the Illiois Pollution Control Board at all times and sites except Station A during P1. In 65% of fecal samples where FC and FS were present, the FC: FS ratio indicated that the source of the fecal matter is both human and animal.

TABLE 28

Average and standard deviations of Fecal Coliform (FC) and Fecal Streptococus (FS) concentraions for all stations by Water Year and analysis period in number per milliliter.

	Stations					
	A		B		C	
	FC	FS	FC	FS	FC	FS
Water year ($\overline{X}$)	467.4	270.5	704.3	608.2	13494.0	11015.0
standard deviation	2687.1	633.5	1049.4	1337.9	41556.0	3722.0
P_1 ($\overline{X}$)	143.8	81.4	1121.1	1276.7	4206.9	3690.0
standard deviation	249.6	184.6	1608.3	2191.8	6921.0	5380.3
P_2 ($\overline{X}$)	702.7	392.3	502.7	243.6	20248.2	16677.3
standard deviation	2221.5	787.2	453.1	218.1	54366.9	48876.8

Loadings

Calculations of total quantities of solids transported include errors of determination of discharge as well as errors in sampling and determining concentrations of suspended solids. The automatic water samplers used in this study have recognized limitations in sampling for suspended solids on a time basis. Moderate to high flows having a velocity over 15 cfs in the channel could transport large amounts of suspended solids downstream undetected by the automatic sampling equipment. Overall, the estimation of suspended solids transport in tons should have an accuracy of ± 15%.

To relate total suspended solids concentration to total suspended solids load the following equation was used:

Total Suspended Solids Load (tons/day) = total suspended solids concentration (mg/l) * streamflow (cfs) *0.0026928

The sediment load carried by a stream is a function of a number of variables. The major ones are:

1. The characteristics of the watershed, such as soils, forest cover and agricultural practices.
2. The meteorological conditions, such as rainfall and runoff characteristics, and snow and ice melt.

3. Physical features, determined by land use and urbanization practices. The nature of the bed and bank material, soil cover, bank cover, and characteristics of the tributaries or drainage ditches.

4. Man-made constraints, river straightening and channelization, repair or maintenance of stream banks and levees, and construction of bridges (Station B) and dams (Station A). (Ivens, 1981).

The sediment yield of a drainage basin is the resultant of the processes of erosion, transportation and deposition operating in that basin, and its magnitude reflects the sediment delivery ratio. Estimates of the sediment delivery ratio for the Blue Creek Watershed range from 48% (Lee, 1981) to 66% (Davenport, 1982).

The yield per month from the watershed stations varied greatly during water year 1980. Figure 16 summarizes the yield per station per month of total suspended solids transported from all three stations. Table 29 summarizes the yield per station per month of total suspended solids transported in terms of event/non-event transport. Table 30 summarizes the total, event and non-event transport at each station by water year and period of analysis. The seasonal distribution of yield at each station reflects the interaction of precipitation, flow regimes, and sediment availability.

TABLE 29

Total, event, and non-event suspended solids loadings for all stations by month during Water Year 1980, in tons.

Station		A			B			C	
Month	Total	Event	Non-Event	Total	Event	Non-Event	Total	Event	Non-Event
May	2.70	0.18	2.52	31.50	25.40	6.10	50.80	44.60	6.20
June	8.78	4.34	4.44	622.00	618.00	4.00	2351.00	2349.12	1.88
July	0.00	0.00	0.00	1.22	0.00	1.22	0.58	0.00	0.58
August	1.24	0.00	1.24	57.90	56.20	1.70	179.00	174.00	5.00
September	5.44	1.14	4.30	57.80	56.50	1.30	340.00	337.00	3.00
TOTAL	18.16	5.66	12.50	770.42	756.1	14.32	2921.38	2904.72	16.60

Figure 16. Total Suspended Solids Yield Per Station Per Month of Water Year 1980.

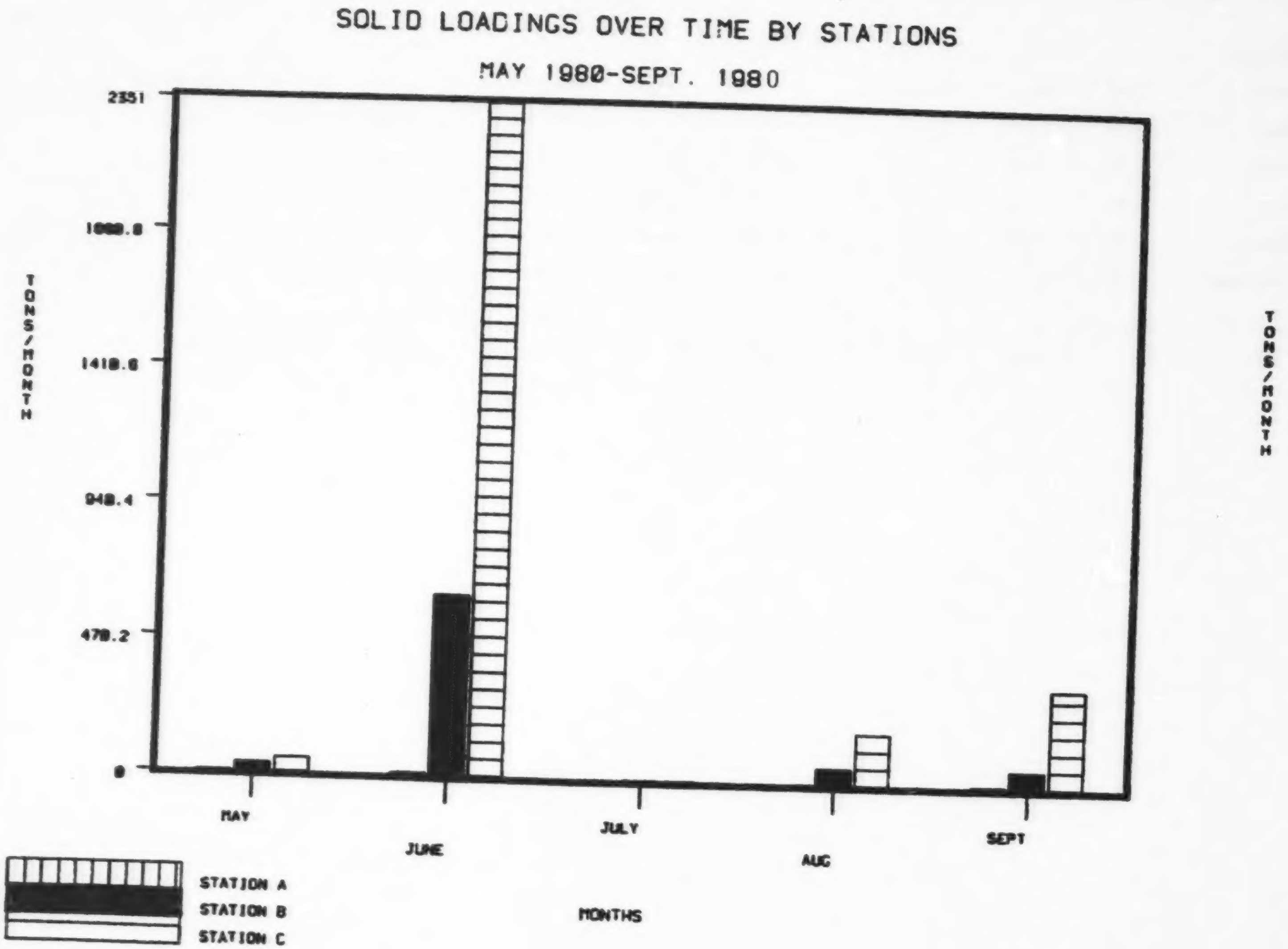


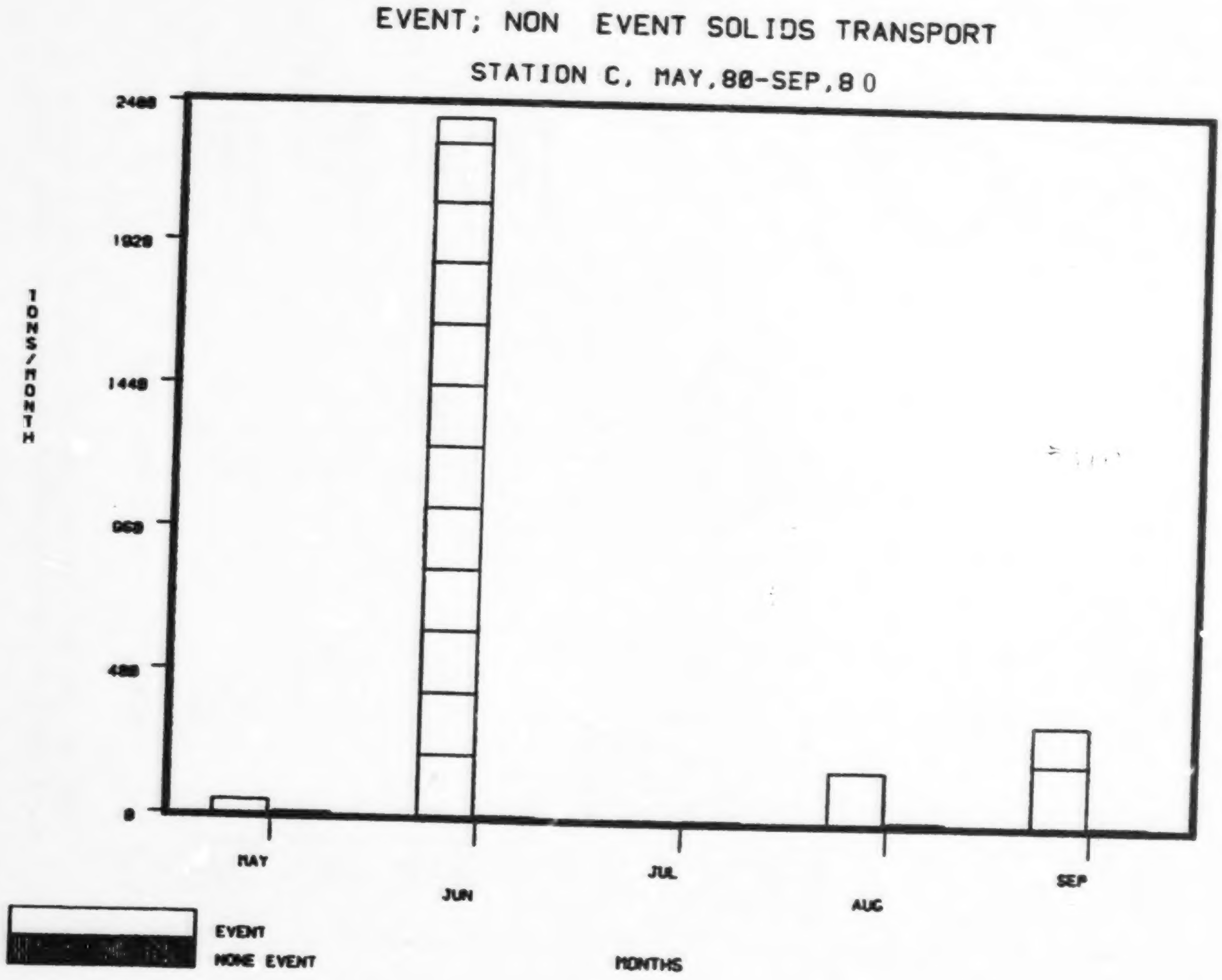
TABLE 30

Total, event and non-event suspended solids transport for each station by Water Year and analysis periods in tons.

		Water Year 1980	P1*	P2**
Station A	Total	18.16	11.48	6.68
	Event	5.66	4.52	1.14
	Non-Event	12.50	6.96	5.54
Station B	Total	770.42	653.50	116.92
	Event	756.10	643.40	112.70
	Non-Event	14.32	10.10	4.72
Station C	Total	2921.38	2401.80	519.58
	Event	2904.62	2393.72	511.00
	Non-Event	16.60	8.08	8.52

*P1: April-June
**P2: July-November

Figure 17. Event; Non Event Solids Transport at Station C, During Water Year 1980.



Tables 12 and 30 show that significant amounts of runoff occurred and total suspended solids were transported during P1 after the soil had been tilled for planting. Intense rainstorms during May and June on bare loessial soils caused surface sealing which reduced infiltration and increased runoff and suspended solids transport. Total suspended solids transported during P2 is significantly less than during P1. Increased surface cover, due to crop growth, offset the 40% increase in rainfall that occurred during P2. About three-quarters of P1's precipitation occurred during storm events, whereas only 40% of P2's precipitation was storm event related.

Total suspended solids transported (Table 30) showed a definite "upstream -- downstream" trend with lower quantities measured downstream. At Station C, about 99% of P1's total suspended solids transport occurred during storm events, during P2 98% was (Figure 17). Station B showed a similar relationship, but the total quantity measured was 26% of Station C's quantity. The flow constriction device at Station B causes differential velocities in storm flow to occur between Station B and C thus allowing the suspended matter to settle out in pools. Station A is dissimilar from Stations B and C due to the effect of the lake. The concentrations found lake bottom samples were always higher than those in the surface, this was due to the settling of particulate matter from the epilimnion, according to Stokes law. Water quality samples taken at Station A represent only surface water conditions.

Extrapolation of Station B's quantity to the entire watershed would estimate 1080 tons of suspended solids was delivered to the lake, during the five month measurement period. This should be considered as a minimum quantity due to changes in land use/cover and spatial variation in the remainder of the watershed. Combining this estimate with what was measured at Station A and what was removed by the water treatment plant (3.3 tons) would indicate nearly 1058 tons of suspended solids (98%) settled out or are in bottom water suspension within the lake. A reservoir trap efficiency of 93% was predicted from the Brune Reservoir trap efficiency curve (Bogner, 1979). The 5 month period of Water Year 1980 indicated the reservoir trap efficiency was 98%. The higher trap efficiency probably results from the longer residence time wihin the lake due to below normal precipitation during this period.

Lake

Pittsfield City Lake is a 218 acre impoundment that was constructed in 1961 as a multiple purpose reservoir. It is utilized as public water supply and for recreation by the surrounding area. The lake has a maximum depth of 32 feet and a mean depth of 12 feet. The watershed area/lake capacity ratio is 2.5, while the mean hydraulic retention time is 0.554 years (Table 31). Pittsfield City Lake is classified as an artificial central lake due to its geographic location and being man-made.

The water quality and use characteristics of Pittsfield City Lake are being monitored to determine the impacts of RMS's implementation within the watershed upon lake water quality. The monitoring effort of the lake consists of two components: 1) an intensive 4 year monitoring program in the lake and 2) an evaluation of the Pittsfield City Water Treatment plant's records. There are three main lake sampling locations. The water quality monitoring program includes sampling for physical/chemical and biological parameters. Wide scan toxic substance analyses are being done on fish flesh, macroinvertebrates, bottom sediments, and whole water. Water quality data from the Pittsfield City Water Treatment Plant dating back to 1965 was available.

TABLE 31

Location, physical description and morphometry of Pittsfield City Lake, Pike County, Illinois.*

Lake

Latitude	39° 37' 51"
Longitude	90° 44' 46"
Basin	Illinois River
Segment	B-06
Normal pool elevation	596 ft.
Maximum length	1.5 mi.
Surface acres	218
Maximum depth	32 ft.
Length of shoreline	5.20 miles
Bottom slope	0.3617
Storage volume	2773 acre-feet
Retention time	0.554 year
Annual capacity loss	1.08%
Total original capacity loss	19.7%

Watershed*

Major tributary	Blue Creek
Drainage area	11.1 mi^2 (7,028 acres)
Area excluding lake	10.6 mi^2 (6810 acres)

*IEPA, 1980

Turbidity at the Water Treatment Plant

Turbidity is the term used to describe the degree of opaqueness produced in water by suspended particulate matter. The kinds of materials creating turbid conditions in a given body of water are as varied as the biotic and abiotic composition of the surrounding terrain, inflowing streams, and the lake itself. Silt, clay, particulate organic and inorganic matter, plankton and other microorganism may all contribute substantially to the quantity and proportions of particulate matter available. The nature of materials causing turbidity is important, because of its physical properties, potential chemical interactions, and total loads. Turbidity is not a uniform parameter since the quantity and quality of suspended particulate matter is so variable in nature (Reid, 1961).

Turbidity has been measured at the Pittsfield Water Treatment Plant since June, 1976. The results are expressed in NTU's (Nephelometric Turbidity Units) which are based on standards prepared from a formazin polymer (APHA, 1980).

Figure 18 indicates that mean monthly turbidity in water taken from Pittsfield City Lake has been increasing. Close inspection of the data reveals, as expected, a general trend of lower turbidity levels during December, January and February. Historically, these months have low levels of precipitation usually only 13% of the long term annual. Whereas, peak concentrations are expected during April and May due to the normal precipitation and land management patterns within the watershed. Land management activities during April and May are usually related to planting and seedbed establishment which cause soil disturbance and thus expand potential source areas for suspended solids.

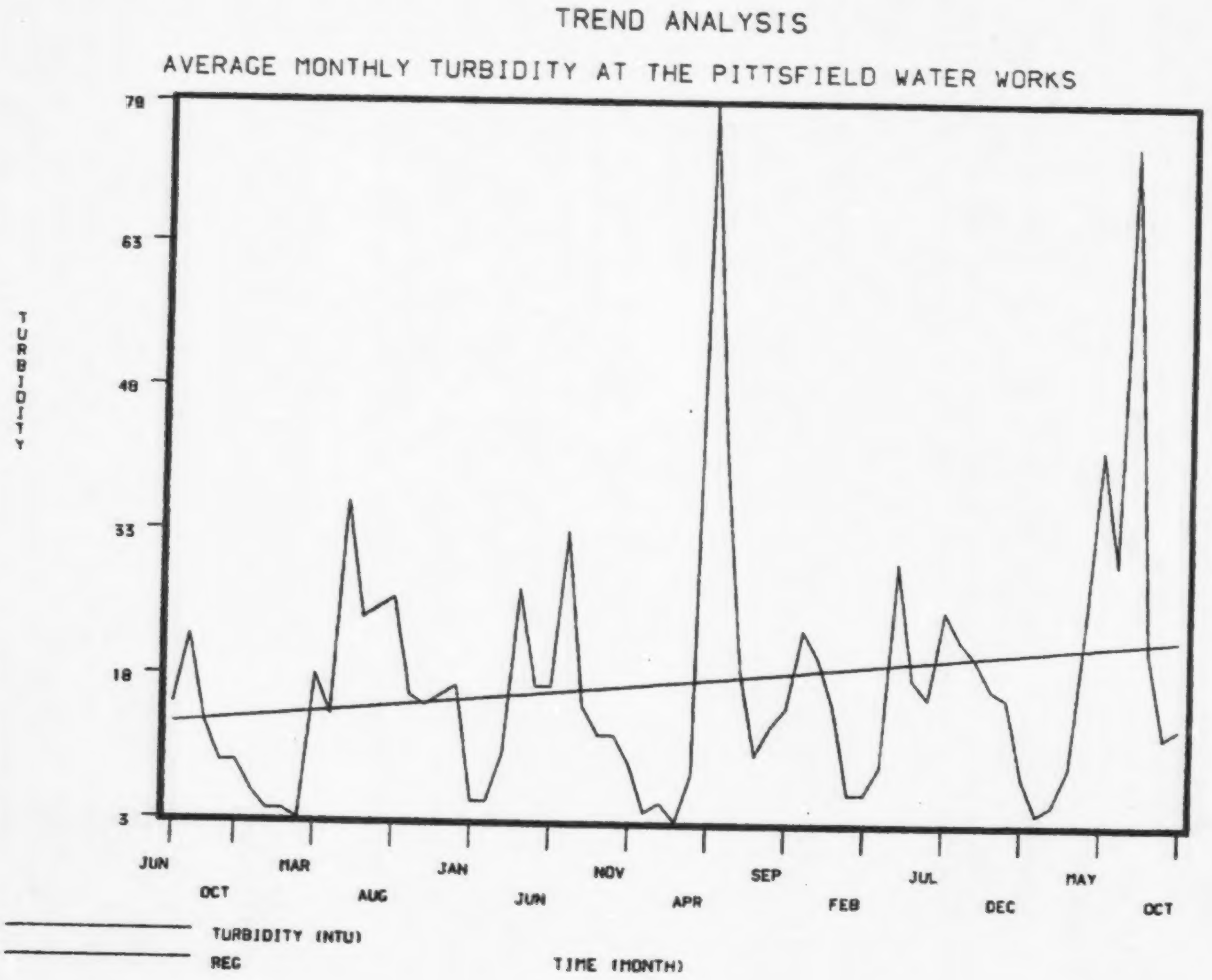
LAKE WATER QUALITY

Pittsfield City Lake was sampled in 1979 and 1980 as part of the Blue Creek Watershed Project. "Limnology of Pittsfield City Lake, 1979' (IEPA, 1980) presents the results of the first year of lake sampling. For water quality parameter significance please refer to the proper subsection of the watershed section.

Secchi

The waters of Pittsfield City Lake are turbid. Secchi disc visibility in 1979 ranged from six inches in May to 40 inches in June and averaged 19 inches; in 1980 visibility ranged from seven inches in June to 45 inches in August and averaged 24.6. Although the average is within reasonable limits the variability of transparency depths limits utility of the lake. Seechi disk visibility is a measure of lake water transparency or its ability to allow vertical light penetration. Secchi disc transparency provides a general index of the clarity of the water and its physical and optical properties, including water color, turbidity, dissolved and suspended organic and inorganic material. The depth of water capable of photosynthesis is called the euphotic zone. This zone generally determines the maximum depth for biological life requiring oxygen to survive and, therefore, limits available habitat and diversity. The one percent light penetration depth is generally defined as the lower limit of the euphotic zone. (IEPA, 1980).

Figure 18. Mean Monthly Turbidity at the Pittsfield City Water Plant.



TREND ANALYSIS

AVERAGE MONTHLY TURBIDITY AT THE PITTSFIELD WATER WORKS

In assessing the results of the National Eutrophication Survey, Allum et. al. (1977) classified oligotrophic lakes as those with Secchi depths in excess of 3.7 meters (12.1 feet). Mesotrophic lakes had Secchi depths between 2.0 and 3.7 meters (6.6 and 12.1 feet), while those with Secchi transparency of less than 2.0 meters (6.6 feet) were eutrophic (Sefton, 1978).

Based on the above classification, Pittsfield would be considered eutrophic (mean Secchi transparency of 2 ft.). A spatial trend in Secchi was found, with the least transparency generally recorded at the headwaters site with increased values down - lake. Temporally, Secchi disk visibility measured after periods of rainfall was the least; greatest measurements were recorded after periods of no precipitation. Complete Secchi disk data is presented in the Appendix Section.

Secchi disk visibility increased from P1 to P2. This increase in visibility results from lower surface water suspended solid concentrations during crop maturation and growth.

Mean transparency in other artificial Central Illinois lakes during 1980 (Table 32) ranged from 13 in. (Lake Decatur) to 59 in. (Lake of the Woods). Pittsfield City Lake had the transparency value (7 in.) of all the lakes in this comparison.

Turbidity

The mean turbidity in surface waters of Pittsfield City Lake was 7.3 NTUs in 1980 (22.0 NTUs-1979). The mean bottom water turbidity was 9.6 NTUs (1979-36.5 NTUs). 1980 was below normal in terms of precipitation (Refer to Table 35) while 1979 was 5.29 below normal.

Minimum values for the turbidity in-lake water samples were recorded in August, except at site 2, where the minimum turbidity was observed in September. Highest turbidity values were observed in June. This pattern correlates with the land management activities being carried out in the watershed and the precipitation. Periods of low turbidity correspond to the period when the agricultural canopy cover was nearly 100%. Complete turbidity data is presented in the Appendix Section.

The turbidity of Pittsfield City Lake is compared to other central Illinois impoundments in Table 32. Although Lake of the Woods had a mean transparency of over twice that of Pittsfield City Lake, their surface water turbidity values are equal. Lowest mean surface water turbidities were found in Pittsfield, Otter and Lake of the Woods (9 NTUs) and the highest in Decatur (12 NTUs) and Springfield (14).

Suspended Solids

Concentrations of total (TSS) and volatile suspended solids (TVS) in Pittsfield City Lake are presented in the Appendix Section. Mean values for samples taken during 1980 were 25.0 and 5.0 mg/l for TSS and TVS, respectively. In 1979, TSS and TVS were 32.0 and 6.0 mg/l respectively. On the average in 1980, TVS comprised 21% of TSS. In surface water samples the percentage of TVS comprised by TVS ranged from 21 to 24%; whereas at both bottom water sites VSS comprised 20% of TSS. This indicates the suspended solids were probably inorganic in nature. Inorganic suspended soils in many Illinois lakes result largely from soil erosion and the subsequent runoff of soil particles into reservoir tributaries (Sefton, et al 1980). Maximum observed values for TVS and VSS were 92.0 mg/l and 23.0 mg/l, while minimum values were 5.0 mg/l and 0.0, respectively. Maximum and minimum values for both TSS and TVS were lower in 1980 when compared to 1979 values.

There appears to be a definite "upstream-downstream" difference in TSS and TVS. Site 3 in the lake, the headwaters, had much higher values for suspended particulate matter than downstream sites 2 and 1. TSS and TVS concentrations in bottom water samples were always greater than those found in top water samples. The definite "upstream-downstream" difference in bottom water is the complete opposite of that found in surface water, with site 1 having the higher TSS and TVS values. This is due to the settling of particulate matter from the epilimnion, according to Stokes law.

TABLE 32

Water Quality Data, Central Artificial Lakes, 1980

Lake Name	County	Surface NO2-NO3	Surface NH3-N	Surface TKN	Surface T-PHOS	Surface D-PHOS	Bottom NO2-NO3	Bottom NH3-N	Bottom TKN	Bottom T-PHOS	Bottom D-PHOS
Otter	Macoupin										
Lake Mean		0.13	0.06	0.86	0.94	0.00	0.08	0.59	1.36	0.10	0.05
Standard Deviation		0.14	0.04	0.26	0.02	0.00	0.00	0.44	0.42	0.07	0.08
Lake Minimum		0.00	0.01	0.60	0.01	0.00	0.00	0.11	1.00	0.02	0.00
Lake Maximum		0.30	0.10	1.30	0.08	0.01	0.20	1.20	2.00	0.25	0.20
Number of Obser		6.00	6.00	6.00	5.00	6.00	6.00	6.00	6.00	6.00	6.00
Pittsfield	Pike										
Lake Mean		0.17	0.18	0.85	0.07	0.03	0.17	1.03	1.81	0.23	0.08
Standard Deviation		0.13	0.14	0.23	0.03	0.01	0.15	1.33	1.54	0.21	0.07
Lake Minimum		0.00	0.00	0.60	0.03	0.01	0.00	0.01	0.50	0.04	0.01
Lake Maximum		0.38	0.70	1.40	0.19	0.07	0.39	3.98	5.60	0.666	0.27
Number of Obser		21.00	21.00	21.00	21.00	21.00	12.00	12.00	12.00	12.00	12.00
Springfield	Sangamon										
Lake Mean		1.11	0.10	0.70	0.16	1.36	0.11	0.72	0.16	0.18	
Standard Deviation		1.64	0.06	0.33	0.06	0.03	1.77	0.03	0.21	0.03	0.02
Lake Minimum		0.06	0.02	0.10	0.10	0.00	0.06	0.07	0.40	0.12	0.07
Lake Maximum		4.30	0.21	1.10	0.27	0.18	4.40	0.17	1.00	0.22	0.13
Number of Obser		6.00	6.00	6.00	6.00	5.00	5.00	5.00	5.00	5.00	5.00
L. of the Woods	Champaign										
Lake Mean		0.06	0.06	0.68	0.03	0.00	0.06	0.08	1.70	0.17	0.13
Standard Deviation		0.05	0.04	0.08	0.00	0.00	0.05	0.99	1.06	0.18	0.16
Lake Minimum		0.00	0.01	0.60	0.20	0.00	0.00	0.05	0.80	0.03	0.00
Lake Maximum		0.10	0.10	0.80	0.04	0.01	0.10	2.40	3.00	0.50	8.43
Number of Obser		5.00	5.00	5.00	5.00	5.00	6.00	6.00	6.00	6.00	6.00
Decatur	Macon										
Lake Mean		3.71	0.09	1.26	0.16	0.94	4.88	0.09	1.12	0.11	0.02
Standard Deviation		4.66	0.04	0.28	0.10	0.03	4.63	0.01	0.02	0.02	0.02
Lake Minimum		0.01	0.03	0.90	0.09	0.01	0.75	0.07	0.90	8.08	0.81
Lake Maximum		9.30	0.16	1.70	0.33	0.09	9.00	0.10	1.30	9.13	0.06
Number of Obser		5.00	5.00	5.00	5.00	5.00	4.00	4.00	4.00	4.00	4.00

Water Quality Data, Central Artificial Illinois Lakes, 1980

Lake Name	COUNTY	Surface							Bottom						
		SECCHI	TURB	VSS	TSS	COND	COD	CHLORIDE	TURB	VSS	TSS	COD	COND	CHLORIDE
Otter	Macoupin													
Lake Mean		42.50	4.25	1.83	8.33	224.50	10.66	12.50	9.83	3.83	15.50	17.50	309.40	11.83
Standard Deviation		23.37	2.36	1.32	5.61	74.63	2.94	0.83	4.40	1.16	5.20	3.20	37.54	1.16
Lake Minimum		18.00	1.50	0.00	1.00	134.00	15.00	12.00	6.00	2.00	11.00	15.00	265.00	11.00
Lake Maximum		76.00	8.00	4.00	16.00	312.00	23.00	14.00	18.00	5.00	23.00	22.00	355.00	14.00
Number of Obser		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Pittsfield	Pike													
Lake Mean		24.55	7.27	3.76	16.40	268.52	28.09	9.48	9.60	7.75	38.58	24.75	340.87	0.68
Standard Deviation		10.92	10.22	3.00	12.02	67.50	31.67	1.34	7.69	5.87	20.24	12.36	52.82	1.41
Lake Minimum		7.00	1.00	0.00	5.00	125.00	15.00	8.00	2.00	2.00	12.00	15.00	300.00	8.38
Lake Maximum		45.00	44.00	13.00	60.00	328.00	164.00	13.00	26.00	23.00	92.00	55.00	440.00	13.00
Number of Obser		20.00	18.00	21.00	20.00	17.00	21.00	21.00	10.00	12.00	12.00	12.00	8.00	12.00
Springfield	Sangamon													
Lake Mean		16.75	12.66	4.16	18.33	393.83	14.83	22.50	14.40	5.40	24.40	17.20	30.00	21.80
Standard Deviation		8.55	7.94	2.13	8.33	11.60	1.94	2.88	10.45	1.34	11.32	8.92	0.66	2.16
Lake Minimum		7.00	5.00	2.00	7.00	380.00	12.00	18.00	6.00	4.00	16.00	12.00	385.00	18.00
Lake Maximum		32.00	28.00	7.00	29.00	408.00	17.00	27.00	32.00	7.00	43.00	44.00	400.00	23.00
Number of Obser		6.00	6.00	6.00	6.00	6.00	6.00	6.00	5.00	5.00	5.00	5.00	5.00	5.00
L. of the Woods	Champaign													
Lake Mean		58.66	7.33	2.50	4.66	3945.16	17.80	36.80	9.50	4.33	7.33	19.83	440.83	36.83
Standard Deviation		18.87	3.20	1.04	1.03	18.55	0.83	2.68	5.95	2.87	2.33	3.18	49.23	0.75
Lake Minimum		32.00	2.00	1.00	4.00	360.00	17.00	31.00	3.00	0.00	5.00	17.00	380.00	36.00
Lake Maximum		80.00	11.00	4.00	6.00	415.00	10.00	37.00	20.00	9.00	11.00	25.00	495.00	36.00
Number of Obser		6.00	6.00	6.00	6.00	5.00	5.00	5.00	5.00	6.00	6.00	6.00	6.00	5.00
Decatur	Macon													
Lake Mean		13.00	8.40	5.00	36.20	628.00	28.20	24.89	12.75	6.50	33.00	16.75	522.50	21.75
Standard Deviation		5.91	5.41	3.11	25.63	181.55	6.69	4.43	10.17	4.65	12.38	2.21	54.23	3.09
Lake Minimum		6.00	5.00	2.00	18.00	465.00	13.00	20.00	7.00	0.08	22.00	14.00	475.00	19.00
Lake Maximum		20.00	18.00	0.00	9.00	940.00	31.00	5.00	4.00	4.00	4.00	4.00	4.00	4.00
Number of Obser	5.000	5.00	5.00	5.00	5.00	5.00	5.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

TABLE 33

Water quality summary for Pittsfield City Lake
RD-B06-P

Parameter	Surface					Bottom					Lake					Units
	Mean	Std	Min	Max	# of obs	Mean	Std	Min	Max	# of obs	Mean	Std	Min	Max	# of obs	
NO2-NO3	0.18	0.130	0.00	0.300	21	0.17	0.15	0.00	0.39	12	0.17	0.37	0.00	0.39	33	mg/l
NH3-N	0.10	0.15	0.00	0.70	21	1.04	1.34	0.01	3.97	12	0.44	0.96	0.00	3.87	33	mg/l
TKN	0.86	0.23	0.50	1.40	21	1.82	1.55	0.50	4.50	12	1.21	1.02	0.50	5.60	33	mg/l
T-PHOS	0.70	0.04	0.04	0.19	21	0.24	0.21	0.04	0.55	12	0.14	0.39	0.04	0.66	33	mg/l
D-PHOS	0.03	0.02	0.02	0.67	21	0.08	0.08	0.01	0.27	12	0.05	0.23	0.10	0.27	33	mg/l
TURB	7.28	10.23	1.00	44.00	18	9.60	7.69	2.00	26.00	12	8.10	9.30	1.00	44.00	30	NTU
VSS	3.76	3.08	0.00	13.00	21	7.75	5.87	2.00	23.00	12	5.20	4.60	0.00	23.00	33	mg/l
TSS	16.40	12.02	5.00	50.00	20	38.58	20.25	12.00	92.00	12	24.72	4.34	5.00	92.00	32	mg/l
TEMP	20.98	9.98	3.00	31.90	21	14.45	9.14	3.00	31.00	10	18.87	10.00	3.00	31.90	31	oC
DO	8.19	2.42	5.30	13.90	21	5.35	5.68	0.00	13.00	10	0.80	4.10	0.00	13.90	31	mg/l
COD	28.10	31.68	15.00	164.00	21	24.75	12.37	15.00	55.00	12	26.90	26.10	15.00	164.00	33	mg/l
COND	268.53	67.50	125.00	328.00	17	340.88	52.82	300.00	440.00	8	291.70	71.00	125.00	440.00	25	umhos/cm
T-ALK	123.60	35.92	0.00	146.00	15	159.70	37.08	100.00	200.00	10	136.40	40.30	0.00	200.00	25	mg/l
FECAL	117.14	237.99	10.00	900.00	14	-1	-1	-1	-1	0	117.14	237.99	10.00	900.00	14	# organisms per/100 ml
CHLORIDE	9.49	1.34	8.00	13.00	21	9.68	1.41	8.30	13.00	12	9.56	1.16	8.00	13.00	33	mg/l
SEECHI	24.65	10.92	7.00	45.00	20	-1	-1	-1	-1	0	24.6	10.90	7.00	45.00	20	inches

Seasonally surface TSS and TVS values decrease between P1 and P2. This could result from canopy establishment during P2 and the decrease in source area.

For comparison purposes, suspended solids for other Illinois impoundments are presented in Table 32. Lake Decatur exhibited the highest mean surface TSS value ($\bar{X}$ = 36.2), while the lowest mean ($\bar{X}$ = 4.6 mg/l) was recorded in Lake of the Woods. The lowest mean bottom TSS value ($\bar{X}$ = 7.3 mg/l) was recorded in Lake of the Woods, while the highest value ($\bar{X}$ = 38.8 mg/l) was measured at Pittsfield City Lake. The highest single value observed among these five artificial central lakes (92.0 mg/l) was obtained from a water sample taken in Pittsfield City Lake.

Sefton (1980) cautions comparing lakes by mean TSS values since it appears that many means are disproportionately influenced by the relatively high values found at the upper end of lake end. They suggest that it may be more meaningful to look at lake site means.

Nitrate-Nitrite (NO3-NO2-N)

NO_3 & NO_2-N values show a definite "upstream-downstream" difference. Site 3, at the headwaters, had much higher values than sites 2 and 1. NO_3 & NO_2-N concentrations did not exceed the Illinois Pollution Control Boards' (1977) limit of 10 mg/l and 1 mg/l respectively.

NO_3 & NO_2-N concentrations decreased from P1 to P2 at all lake sites. This decrease can be attributed to uptake by algae throughout summer, decrease in land inputs, and dilution. Mean surface water concentrations (0.17 mg/l) shows little variation from mean bottom water concentrations (0.17 mg/l). There is considerable variation between 1979 and 1980 values, no trends are easily definable. Complete NO_3 & NO_2-N data is presented in the Appendix Section.

Of Central Illinois impoundments sampled in 1980, Lake Decatur exhibited the highest mean surface NO_3-NO_2-N concentration ($\bar{X}$ = 3.71 mg/l), while Lake of the Woods exhibited the lowest mean ($\bar{X}$ = 0.60 mg/l). The lowest bottom NO_3-NO_2-N concentration ($\bar{X}$ = 0.50 mg/l) was recorded in Lake of the Woods, while the highest bottom concentration ($\bar{X}$ - 4.88 mg/l) in Lake Decatur.

Total Ammonia Nitrogen (NH3-N)

The Illinois Pollution Control Board (1977) specified that NH_3-N should not exceed 1.5 mg/l for general use waters. Ammonia (NH_3-N) concentrations in Pittsfield City Lake ranged from 0.0 to 3.87 mg/l, with site 1 bottom samples having the highest mean concentrations ($\bar{X}$ = 1.83) and at bottom site 1 the water is anoxic water due to its depth and thermal stratification. Mean NH3-N concentrations in the surface waters were between 0.06 and 0.18 mg/l; highest surface water concentration occurred in September. This exceeds the 0.02 mg/l limit USEPA recommended for the protection of aquatic life.

Total Kjeldahl Nitrogen (TKN)

Values for TKN include both NH3-N and organic nitrogen (N). TKN minus NH3-N is equivalent to the organic N level.

Mean TKN concentrations for all Pittsfield City Lake sites were between 0.81 and 2.63 mg/l. Concentrations ranged from 0.50 to 5.60 mg/l, with highest values always being observed in the bottom water samples.

TKN of the bottom water at site 1 averaged 31% organic N, the lowest percentage of all sample sites. This is a 40% decrease over what was measured in 1979. This is the result of increased NH3-N due to anoxic conditions in the hypolimnion. Average organic nitrogen concentration ranged from 0.67 to 0.81 mg/l.

Of the central Illinois impoundments sampled in 1980, Lake Decatur exhibited the highest mean surface TKN concentration ($\overline{X}$ = 1.26 mg/l), while Lake of the Woods recorded the lowest mean ($\overline{X}$ = 0.68). The highest mean bottom TKN concentration ($\overline{X}$ = 1.82 mg/l) was recorded in Pittsfield City Lake, while the lowest mean concentration ($\overline{X}$ = 0.72 mg/l) was recorded in Lake Springfield. The highest single value observed among these artificial central lakes (5.60 mg/l) was obtained on a bottom water sample taken in Pittsfield City Lake.

Total Phosphorus (TP)

The Illinois Pollution Control Board (1977) general use standard for TP is 0.05 mg/l. In assessing the 1973 National Eutrophication Survey results Allum et. al. (1977) classified oligotrophic lakes as those with TP values below 0.01 mg/l and mesotrophic as those with TP values between 0.01 and 0.02 mg/l. Eutrophic lakes had TP values greater than 0.02 mg/l (Sefton, 1978).

Based upon the above classifications, Pittsfield City Lake would be considered eutrophic ($\overline{X}$ = 0.14 mg/l). This classification corresponds to that based on secchi transparency. TP concentrations nearly always exceeded the 0.05 mg/l standard.

There was a 'upstream-downstream' decrease in surface TP concentration from site 3 ($\overline{X}$ = 0.10 mg/l) to site 1 ($\overline{X}$ = 0.06 mg/l). The high TP at site 3 can be expected because of its location in the shallow headwaters of the lake (IEPA, 1980). TP at site 3 is lower than that measured at watershed Station B.

The mean bottom sample values from sites 1 and 2 were 0.36 and 0.11 mg/l, respectively. The high TP in the bottom water at site 1 can be expected because of the existence of anoxic conditions (Stumm, 1970) and the release P from particulate matter settling from the epilimnion.

Mean surface TP concentrations among the five central artificial lakes ranged from 0.03 mg/l (Lake of the Woods) to 0.17 mg/l (Lake Springfield), Pittsfield City Lake had a mean concentration of 0.08 mg/l. Pittsfield City Lake exhibited the highest mean bottoms TP concentration (X = 0.24 mg/l), while Otter Lake recorded the lowest mean TP concentration (X = 0.10 mg/l). The highest single value observed among these lakes (0.66 mg/l) was obtained on a water sample taken in Pittsfield City Lake.

Dissolved Phosphorus (DP)

Mean dissolved phosphorus (DP) was higher in the bottom water of site 1 (0.120 mg/l) than at any other sample site. In surface water, the DP comprised approximately 41% of the TP, this is an increase of 15% over 1979. In bottom water, DP comprised 33% and 37% of TP at sites 1 and 2, respectively. The percentage of TP that is dissolved in bottom water in 1980 is slightly higher than in 1979.

The increased DP percentage of TP could result from the implementation of conservation tillage systems (Table 9). Barasis (1978) attributes high DP losses from conservation tillage systems to a lack of incorporation of broadcast P fertilizers and he also suggest that leaching of plant tissue may be an additional source. Conservation tillage reduces TP concentrations due to controlling particulate matter transport from the field (Mueller, 1981).

Lake Springfield exhibited the highest mean surface DP concentration ($\overline{X}$ = .13 mg/l) of central Illinois impoundments sampled in 1980, while Otter Lake recorded the lowest ($\overline{X}$ = 0.01 mg/l). Mean bottom DP concentrations among the five central artifical lakes ranged from 0.02 mg/l (Lake Decatur) to 0.13 mg/l (Lake of the Woods), Pittsfield City Lake's concentrations ranged from 0.01 mg/l to 0.27 mg/l.

Conductivity

A measure of the total amount of ionized material in water can be obtained by determining its electrical conductance. Pure water has a very low electrical conductance. However, the presence of charged particles (ions) in solution makes the solution conductive (IEPA, 1980).

Conductivity data for Pittsfield City Lake are presented in the Appendix Section. Surface conductivity varied from 125 to 328 umhos/cm and averaged 268 umhos/cm in Pittsfield City Lake during 1980. Bottom conductivity ranged from 300 to 440 umhos/cm, with a mean value of 323 umhos/cm. The 1980 maximum and mean values for both surface and bottom water were below 1979 values.

Chloride (Cl)

The major influence of Cl in aquatic systems is exerted by its contribution to salinity thus affecting the overall habitability of the environment by virtue of its effect on the osmorequaltory ability of aquatic organisms. The Illinois Pollution Control (1977) has set the general water quality standards for state water such that Cl concentration shall not exceed 500 mg/l.

Cl concentrations in Pittsfield City Lake varied from 8.0 to 13.0 mg/l (Table 33). The mean surface water concentration 9.5 mg/l Cl, slightly lower than the bottom water mean of 9.7 mg/l. The 1980 mean surface and bottom water Cl concentrations were slightly higher than 1979 concentrations, 8-2, and 7.8 mg/l Cl, respectively.

Fecal Coliform (FC)

The Illinois Pollution Control Board (1977) has determined that FC levels below 200/100 ml of water sample should be adequate to protect the 'States' water for aquatic life, agricultural use, primary and secondary contact use" (IEPA, 1980).

The mean FC values for Pittsfield City Lake were (255/100 ml) in 1980. Levels at Site 3 (255/100 ml) were substantially higher than those levels at sites 1 (50/100 ml) and 2 (74/100 ml). The 1979 data indicated that FC levels appeared to be elevated after rainfall events. The 1980 FC sampling dates were all preceded by at least one week of no rainfall. The 1980 values are substantially lower than the 1979. Laterally, there is a definite 'upstream-downstream' trend. This results from FC deposition within the lake. FC concentrations are diluted by the resident lake water, and disappear from the water column by sedimenting out. According to Sefton, Geldreich in 1960, found a 95% reduction in FC after the 1st day and 99% reduction after the 2nd.

Alkalinity

Alkalinity is a measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, biocarbonates, and hydroxides, and less significantly, borates, silicates, phosphates, and organic substances (McNelly et. al. 1979). Alkalinity in lakes is primarily governed by the geochemistry of the watershed, and is expressed as an equivalent of calcium carbonate ($CaCO_3$). The Illinois Pollution Control Board has not stipulated a standard for alkalinity in natural waters (IEPA, 1980).

Total alkalinity concentrations in surface water samples from Pittsfield City Lake ranged from 120.0 to 146.0 mg/l $CaCO_3$, with a mean value of 123.6 mg/l $CaCO_3$. The bottom water alkalinity values ranged from 100.0 to 200.0 mg/l $CaCO_3$, with a mean value of 160.0 mg/l $CaCO_3$. Groundwater flow may have raised the alkalinity of the bottom to higher levels.

Chemical Oxygen Demand

Chemical Oxygen Demand (COD) was not sampled in 1979. 1980 COD values exhibited a definite 'upstream-downstream' pattern, site 3 (42 mg/l) highest and site 1 (20 mg/l) lowest. COD values in surface water ranged from 15 to 164 mg/l and averaged 28 mg/l. Bottom water COD values averaged 25 mg/l and ranged from 15 to 55 mg/l (Table 33).

Lake inflow, Station B, COD values averaged 26 mg/l and at Lake Site 3 averaged 42 mg/l (Figure 2). This increase could result from sediment oxygen demand associated with the deposition and sedimentation that occurs between Station B and site 3. The differences between site 1 (X = 20.0 mg/l) and Station A (19.9 mg/l) are not significant.

Pittsfield City Lake exhibited the highest mean COD value

($\overline{X}$ = 28.09 mg/l) of the artificial central lake sampled in 1980, while

Lake Springfield recorded the lowest ($\overline{X}$ = 14.83 mg/l). The highest single value observed among these five lakes (164.00 mg/l) was obtained on a water sample taken in Pittsfield City Lake. Mean bottom COD ranged from 16.75 mg/l (Lake Decatur) to 24.75 mg/l (Pittsfield City Lake).

Summary

1. Background: The Illinois Environmental Protection Agency (IEPA) in cooperation with the United States Department of Agriculture Agencies, Agricultural stabilization and Conservation Service (ASCS) and Soil Conservation Service (SCS), is evaluating the impact of Resource Management Systems (RMS's) implemented under the ACP Special Water Quality Project in the Blue Creek Watershed; Pike County, Illinois. The primary objectives of this project are to identify the most viable agricultural non-point source (NPS) control strategy, demonstrate its effectiveness, develop a methodology to identify land causing water quality problems and to determine the appropriate RMS's.

2. Investigation: The physical, biological, and chemical characteristics of the Blue Creek Watershed were studied during Water Year 1980. A comprehensive monitoring network for the entire Blue Creek Watershed was established by IEPA to document the basic hydrological, meterological, and water quality factors of the project area. The duration, timing and quantity of NPS pollutants were evaluated to determine land management effects on the water quality/quantity budget. Methods used for field and laboratory procedures are those accepted for agricultural related hydrology research. Analytical techniques are documented, but not detailed.

3. Results: Three periods based on the amount of surface cover and land management activities, were selected for evaluating seasonal variaton in streamflow constitutent concentrations and transport. These periods are: P1-fertilizer and seedbed establishment period (April-June); P2-reproduction and maturation period (July-November); and P3-residue period (December-March).

    A. Hydrology: Variability of streamflow was attributed primarily to precipitation patterns and land cover, precipitation was 17.8% below normal. High flows were measured from February through June while lower flows were measured during July and August. The rainfall-runoff ratio ranged from 1.5% in July to 64.5% during February and averaged 8.0% for the ten month period recorded.

    B. Streamflow Constitutents Concentrations: A total of 27 water quality parameters were evaluated at three water quality stations in the Blue Creek Watershed during Water Year 1980. There was an inverse relationship between increased drainage area and water quality constituents evaluated several parameters assessed exhibited general seasonal trends (TSS, VSS, TP, NO_3 & NO_2-N, NH_3-N, BOD and COD). Higher concentrations were measured during P1 than during P2. Treflan, Dieldrin, Atrazine, and Lasso were the only pesticide compounds in measurable quantities. The FC:FS ratios indicates that the source of the fecal matter is both human and animal.

C. Suspended Solids Loadings: Total suspended and volatile solids transported showed a definite "upstream-downstream" trend with lower quantities measured downstream. Over 98% of Water Year 1980's total suspended solids transport occurred during storm events at the upstream stations. The downstream station is dissimilar from the upstream stations due to the effect of the lake. The seasonal distribution of yield at each station reflected the interaction of precipitation, flow regimes and sediment availability. A reservoir trap efficiency of 93% was predicted from the Brune reservoir trap efficiency curve (Bogner, 1979). The 5 month period of Water Year 1980, indicated the reservoir trap efficiency was 98%.

D. Turbidity at the Water Treatment Plant: Mean monthly turbidity values in water taken from Pittsfield City Lake since 1976 have been increasing. There are definite seasonal trends, these result from the normal precipitation and land management activity patterns for the watershed. Higher turbidity values occur during the sping and lower values are measured in late summer and early fall.

D. Lake Water Quality: There were obvious seasonal and spatial trends exhibited by several parameters (Secchi, NTU's, TSS, VSS, NO_3 & NO^2-N, TP, DP, FC and COD). Based upon various constituent concentrations, (TP and Seechi) Pittsfield City Lake would be considered eutrophic. The lake quality as indicated by water clarity responded to storm events and generally improved from April through November. Water clarity generally increased from the lake inflow to the dam.

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APPENDIX SECTION

Appendix 1

Laboratory Analyses

All samples requiring laboratory analysis were placed on ice in the field upon collection. Upon arrival at the regional field office, samples were refrigerated and sent to the appropriate IEPA lab. A complete list of parameters sampled during the Blue Creek Watershed study, testing facilities, and summaries of specific analytic procedures are provided below.

Appendix 1

Summary of monitoring parameters. Sample preservation, methods of analysis, reporting units, and Geneal Use Standards as appropriate.

PARAMETER	SAMPLE CONTAINER	PRESERVATION	METHOD OF ANALYSIS (REFERENCE)	UNITS OF MEASUREMENT	DETECTION LIMITS	ANALYSIS	GENERAL USE STANDARD
Temperature			In sit determination using Yellow Springs Instruments (YSI) model 57 dissolved oxygen meter (1).	^oC	nearest 0.1^o	Field determination	
Dissolved Oxygen (DO)			In sit determination using YSI model 57 dissolved oxygen meter (1)	mg/l O_2	0.1 mg/l	Field determination	no less than 5 mg/l
Transparency			Secchi disk (2).	feet	nearest 0.1 foot	Field determination	
Total Suspended Solids (TSS)	1/2 gallon polyethylene	refrigeration at 4^{o}C	filtration on glass fiber filter, determination of increase in weight upon drying at 103-105^{o}C(3, p. 268).	mg/l TSS	1 mg/l	Regional IEPA lab	
Volatile Suspended Solids	1/2 gallon polyethylene	refrigeration at 4^{o}C	Loss in weight of TSS filter upon ignition at 559^{o}C (3, p. 2272).	mg/l VSS	1 mg/l	Regional IEPA lab	
Turbidity	1/2 gallon polyethylene	refrigeration at 4^{o}C	Mephelometrically using Hach model 2100A turbidimeter (3, p. 205).	NTU	0.05 NTU	Regional IEPA lab	
Conductivity			YSIU Model 33 S-C-T Conductivity meter or Electrolytic Conductivity Measuring Set, Model MC-1.	umhos/cm	nearest 1 umhos/cm	Field determination	
Alkalinity			Titration of 10 ml sample with 0.02 N H_2SO_4 to phenolphthalein and brom cresol green-methyl red end points (4).	mg/l $CACO_3$	nearest 5 mg/l	Field determination	

PARAMETER	SAMPLE CONTAINER	PRESERVATION	METHOD OF ANALYSIS (REFERENCE)	UNITS OF MEASUREMENT	DETECTION LIMITS	ANALYSIS	GENERAL USE STANDARD
pH			Sargent-Welch model PBL pH meter, calibrated in field.		nearest 0.1 units	Field determination	in range 6.5-9.0
Nitrate + Nitrite-N	8 oz. polyethylene	10 ml - 20% H_2SO_4/1 at 4°C	Cadmium reduction method on Technicon AutoAnalyzer (3, p. 201).	mg/1 N	0.01 mg/1	Regional IEPA lab	
Ammonia-N (NH_3-N)	8 oz. polyethylene	10 ml - 20% H_2SO_4/1 at 4°C	Phenate method on Technicon AutoAnalyzer (3, p. 168)	mg/1 N	0.01 mg/1	Regional IEPA lab	1.5 mg/1
Total Kjeldahl-N	8 oz. polyethylene	10 ml - 20% H_2SO_4/1 at 4°C	Digestion at 370°C followed by determination of ammonia as above.	mg/1 N	0.1 mg/1	Champaign IEPA lab	
Total Phosphorus	8 oz. polyethylene	10 ml - 20% H_2SO_4/1 at 4°C	Digestion to convert all phosphorus forms to orthophosphate followed by determination using ascorbic acid reduction method using Technicon AutoAnalyzer (3, p. 256).	mg/1 P	0.01 mg/1	Regional IEPA lab	
Total Dissolved Phosphorus (TDP)	1 oz. polyethylene	10 ml - 20% H_2SO_4/1 at 4°C	Field filtration followed by TP analysis as above.	mg1/ P	0.01 mg/1	Regional IEPA lab	0.05 mg/1
Fecal Coliform	6 oz. glass	1 ml - 10% $NA_2S_2O_3$/1	Filtration of sample through 0.45u membrance filter followed by incubation for 24 hrs. at 44.5°C on pad containing M-FC culture media (6, p. 937).	#organisms per/100 ml	1/100 ml	Regional IEPA lab	200/100 ml
Total Mercury	6 oz. glass	20 ml - 25% $K_2CR_2O_7$ in 50% HNO_8/1	Digestion with H_2SO_4 and potassium persulfate to convert all forms to inorganic HG followed by stannous chloride reduction step to convert all inorganic Hg to metalic Hg, then measurement by cold vapor atomic absorption (3, p. 127).	mg/1 Hg	0.05 mg/1	Champaign IEPA lab	0.5 mg/1

Appendix 2

Summary of conservation practices implemented in the Blue Creek Watershed as of September 30, 1980.

CONVERATION PRACTICE	DATE OF INSTALLATION	LOCATIONS: SECTION & TOWNSHIP	ACRES TREATED
lagoon	02/80	29 Griggsville	2
terrace	11/79	3 Newburg	10
waterway	07/80	32 G'ville	15
no till	06/80	29 G'ville	17
no till	06/80	7 Newburg	21
strip cropping	06/80	32 G'ville	43
pond	09/80	17 Newburg	1
structure	09/80	33 G'ville	17
vegetative filter strip	08/80	34 G'ville	2
no till	06/80	34 G'ville	8
no till	06/80	127 Newburg	40
contouring	06/80	17 Newburg	6
no till	06/80	7 Newburg	15
no till	06/80	32 G'ville	24
conservation tillage	06/80	32 G'ville	31
structures (11)	09/80	5 Newburg	10
critical area seeding and pasture improvement	06/80	5 Newburg	32
structure	09/79	5 Newburg	27
terrace	09/79	5 Newburg	50
structures (8)	09/79	8 Newburg	8
terraces (2)	05/80	5 Newburg	33
terrace	09/79	5 Newburg	18
vegetative strip	09/80	5 Newburg	2
waterway	09/80	5 Newburg	26
permanent vegetative cover	06/80	29 & 30 G'ville	12
critical area seeding	06/80	29 & 30 G'ville	3
terrace	09/80	29 & 30 G'ville	3
waterway	09/80	29 & 30 G'ville	36
contouring	09/79	29 & 30 G'ville	38
contouring	09/79	30 G'ville	20
contouring	08/79	34 G'ville	40
no till	06/79	32 G'ville	30
no till	06/79	33 G'ville	37
contouring	08/79	5 Newburg	35
no till	08/79	5 Newburg	7
contouring	08/79	33 G'ville	70

CONVERATION PRACTICE	DATE OF INSTALLATION	LOCATIONS: SECTION & TOWNSHIP	ACRES TREATED
waterway	09/79	8 Newburg	1
no till	06/79	8 Newburg	21
waterway	09/80	33 G'ville	2
no till	06/79	10 Newburg	19
terrace	09/79	32 G'ville	11
no till	06/79	17 Newburg	14
terrace	09/79	31 G'ville	1
contouring	05/79	33 G'ville	21
terrace	09/79	3 Newburg	2
contouring	06/79	29 G'ville	20
structures (2)	09/79	3 Newburg	2
no till	06/79	7 Newburg	15

Appendix 3

Fish population census on Blue Creek at Station C, Pike County, Illinois. July 2, 1980 (IEPA, 1981).

Species	Classification	Number	Size Range (in)
Creek Chub	Tolerant	55	1.3 - 5.4
Suckermouth Minnow	Tolerant	2	2.7 - 2.8
Bigmouth Shiner	Tolerant	19	1.8 - 2.7
Red Shiner	Tolerant	23	1.3 - 2.2
Sand Shiner	Tolerant	21	1.8 - 2.7
Bluntnose Minnow	Tolerant	15	1.6 - 2.9
Black Bullhead	Tolerant	3	2.4 - 2.6

Appendix 4

Description of Artificial Central Illinois Lakes

Otter Lake*

Otter Lake is a 765 acre impoundment located in Macoupin County, Illinois. It was constructed in 1968 as a multiple purpose reservoir. The lake has a maximum depth of 54 feet and a mean depth of 12 feet. The watershed area/lake capacity ratio is 0.8, while the mean retention time is 1.649 years. Land use in the watershed is predominately cropland (80%), with 10, 5, and 5 in woodland, pasture and urban respectively.

Lake Springfield*

Lake Springfield is a 4,024 acre impoundment located in Macoupin County, Illinos. It was constructed in 1935 as a multiple purpose reservoir. The lake has a maximum depth of 40 feet and a mean depth of 13 feet. The watershed area/lake capacity ratio is 3.1, while the mean retention time is 0.482 years. Land use in the watershed is predominately cropland (88%), with 8, 1, 2, and 1 in pasture, woodland, urban, and other, respectively.

Lake of the Woods*

Lake of the Woods is a 25.5 acre impoundment located in Champaign County, Illinois. It was constructed in 1948. It is utilized for recreation by the surrounding area. The lake has a maximum depth of 28 feet and mean depth of 11 feet. The watershed area/lake capacity ratio is 2.1, while the means retention time is 0.634 years. Pasture is the predominate land use in the watershed (0%), while cropland (25%) and parkland (10%) are second and third, respectively. The remainder of the watershed is in various stages of development.

Lake Decatur*

Lake Decatur is a 3,093 acre impoundment located in Macon County, Illinois. It was constructed in 1922 as a multiple purpose reservoir. The lake has a maximum depth of 23 feet and a mean depth of 7 feet. Its annual loss in capacity is 0.88 percent. The watershed area/lake capacity ratio is 26.8, while the mean retention time is 0.030 years. Land use is predominately cropland 90%, with the remainder in pasture (5%), woodland (4%) and urban (1%) use.

*(IEPA, 1978) (Sefton, 1979)

Appendix 5

Discharge in cubic feet per second, Water Year October 1979 to September 1980 near values.

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	-	13	16	17	19	25	20	86	14	5	11
2	-	-	14	16	17	19	24	20	29	15	4	17
3	-	-	14	16	17	20	23	20	40	17	2	11
4	-	-	14	15	17	21	22	19	55	21	1	20
5	-	-	14	16	16	29	21	19	29	21	15	29
6	-	-	14	16	15	29	20	18	25	16	16	24
7	-	-	14	17	16	31	55	17	23	15	11	21
8	-	-	14	17	16	29	43	17	21	14	10	15
9	-	-	14	16	16	24	39	17	20	14	9	14
10	-	-	14	17	16	20	31	17	20	14	8	13
11	-	-	14	18	16	19	28	17	19	12	5	12
12	-	-	14	18	16	20	27	19	18	11	4	12
13	-	-	14	18	16	20	25	26	18	12	2	12
14	-	-	14	17	16	21	27	18	18	9	2	12
15	-	-	14	17	17	26	42	17	18	11	20	12
16	-	-	14	17	18	24	30	19	18	11	52	76
17	-	-	18	16	19	23	28	63	18	11	32	28
18	-	-	18	14	19	20	27	33	18	11	18	17
19	-	-	19	14	20	19	26	25	17	11	15	14
20	-	-	19	13	48	19	25	23	17	10	13	14
21	-	-	18	14	56	19	23	22	17	9	18	13
22	-	-	19	15	26	19	23	22	16	10	12	13
23	-	-	20	15	26	19	23	22	16	10	12	13
24	-	-	32	15	19	31	21	24	17	9	12	12
25	-	-	20	15	19	22	21	23	17	8	12	12
26	-	-	17	15	19	21	21	20	16	8	10	12
27	-	-	17	16	19	20	21	18	15	10	10	11
28	-	-	17	15	19	22	21	18	15	10	10	12
29	-	-	17	16	19	21	20	18	15	9	10	12
30	-	13	17	17	*	89	20	18	14	8	9	13
31	-	*	17	17	*	33	*	19	*	7	11	*
Total	-	13	503	493	583	769	800	671	685	368	368	557
Mean	-	13	16.2	15.9	20.1	24.8	26.7	21.6	22.8	11.9	11.9	18.6
Max	-	13	32	18	56	89	55	63	86	21	52	79
Min	-	13	13	13	16	19	20	17	14	7	1	11

- Missing Data

Appendix 6

1980 AMBIENT LAKE DATA, PITTSFIELD CITY LAKE, PIKE COUNTY, ILLINOIS

DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
Temp										
06/05	23.00	24.10	24.20	23.76	0.66	-1.00	-1.00	-1.00	-1.00	-1.00
06/25	26.60	26.60	28.00	27.06	0.88	12.40	-1.00	-1.00	12.40	-1.00
07/16	31.10	30.00	31.90	31.30	0.52	13.40	-1.00	1.00	13.40	1.00
08/27	28.90	29.20	30.10	29.40	0.62	16.90	26.30	-1.00	21.60	6.64
09/24	21.50	21.90	21.50	21.63	0.23	16.70	-1.00	-1.00	16.70	-1.00
10/29	11.00	11.00	10.00	10.66	0.57	11.00	10.00	-1.00	10.50	0.70
12/03	3.00	3.00	3.00	3.00	0.00	3.00	3.00	-1.00	3.00	0.00
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	20.72	20.05	21.24			12.23	13.10	-1.00	18.87	
STD DEV	20.10	10.25	10.84			5.09	11.95	-1.00	10.00	
MIN	3.00	3.00	3.00			3.00	3.00	-1.00	3.00	
MAX	31.00	30.00	31.90			16.90	26.30	-1.00	31.90	
Fecal										
06/25	30.00	40.00	30.00	33.33	5.74	-1.00	-1.00	-1.00	-1.00	-1.00
07/16	100.00	10.00	30.00	46.66	47.25	-1.00	-1.00	-1.00	-1.00	-1.00
08/27	10.00	10.00	-1.00	10.00	0.00	-1.00	-1.00	-1.00	-1.00	-1.00
09/24	10.00	10.00	60.00	26.66	28.86	-1.00	-1.00	-1.00	-1.00	-1.00
10/29	100.00	300.00	900.00	433.33	416.33	-1.00	-1.00	-1.00	-1.00	-1.00
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	50.00	74.00	255.00			-1.00	-1.00	-1.00	117.14	
STD DEV	46.36	127.00	430.23			-1.00	-1.00	-1.00	237.98	
MIN	10.00	10.00	30.00			-1.00	-1.00	-1.00	10.00	
MAX	100.00	300.00	900.00			-1.00	-1.00	-1.00	900.00	

1980 AMBIENT LAKE DATA, PITTSFIELD CITY LAKE, PIKE COUNTY, ILLINOIS

DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
TSS										
06/05	16.00	30.00	60.00	35.33	22.48	-1.00	-1.00	-1.00	-1.00	-1.00
06/25	7.00	5.00	20.00	10.66	8.14	47.00	35.00	-1.00	41.00	8.48
07/16	11.00	14.00	23.00	16.00	6.24	44.00	36.00	-1.00	40.00	5.65
08/27	-1.00	6.00	11.00	8.50	3.53	47.00	37.00	-1.00	42.00	7.07
09/24	9.00	14.00	17.00	13.33	4.04	92.00	36.00	-1.00	64.00	39.59
10/29	11.00	17.00	23.00	17.00	6.00	30.00	34.00	-1.00	32.00	2.82
12/03	18.00	12.00	12.00	11.33	1.15	12.00	13.00	-1.00	12.50	0.78
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	10.66	14.00	23.71			45.33	31.83	-1.00	24.71	
STD DEV	3.01	8.30	16.71			26.57	9.28	-1.00	4.33	
MIN	7.00	5.00	11.00			12.00	13.00	-1.00	5.00	
MAX	18.00	30.00	60.00			92.00	37.00	-1.00	92.00	
TKN										
06/05	1.10	1.40	1.20	1.23	0.15	-1.00	-1.00	-1.00	-1.00	-1.00
06/25	0.60	0.70	0.90	0.73	0.14	2.60	1.10	-1.00	1.85	1.06
07/16	0.70	0.70	0.90	8.76	0.11	2.00	1.40	-1.00	1.70	9.42
08/27	1.10	0.80	0.90	0.93	0.15	4.00	1.20	-1.00	2.60	1.98
09/24	0.90	0.90	1.20	1.00	0.17	5.60	1.00	-1.00	3.30	3.25
10/20	0.80	0.70	0.70	0.73	0.05	0.80	0.80	-1.00	0.80	0.00
12/03	0.50	0.70	0.60	0.60	0.10	0.80	0.50	0.65	0.21	
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	0.81	0.84	0.91			2.63	1.00	-1.00	1.20	
STD DEV	0.23	0.25	0.22			1.88	0.31	-1.00	1.01	
MIN	0.50	0.70	0.60			0.00	0.50	-1.00	0.50	
MAX	1.10	1.40	1.20			5.60	1.40	-1.00	5.60	

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DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
NH3-N										
06/05	0.10	0.10	0.20	0.13	0.05	-1.00	-1.00	-1.00	-1.00	-1.00
06/25	0.10	0.10	0.10	0.10	0.00	1.90	0.30	-1.00	1.10	1.13
07/16	1.10	0.10	0.10	0.10	0.00	2.10	0.70	-1.00	1.40	0.99
08/27	0.03	0.01	0.04	0.03	0.01	2.96	0.04	-1.00	1.65	1.84
09/24	0.07	0.70	0.02	0.26	0.37	3.97	0.07	-1.00	1.97	2.68
10/29	0.04	0.01	0.03	0.02	0.01	0.12	0.04	-1.00	0.08	0.05
12/03	0.00	0.21	0.00	0.07	0.12	0.01	0.01	-1.00	0.01	0.00
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	0.06	0.17	0.70			1.82	0.245	-1.00	0.44	
STD DEV	0.04	0.24	0.06			1.53	0.264	-1.00	0.05	
MIN	0.00	0.01	0.00			0.01	0.010	-1.00	0.00	
MAX	0.10	0.70	0.200			3.878	0.97	-1.00	3.970	
NO2-NO3										
06/05	0.10	0.20	0.30	0.20	0.10	-1.00	-1.00	-1.00	-1.00	-1.00
06/25	0.10	0.10	0.10	0.10	0.00	0.10	0.10	-1.00	0.10	0.00
07/16	0.10	0.10	0.10	0.10	0.00	0.10	0.10	0.10	-1.00	0.10
08/27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00
09/24	0.18	0.11	0.12	0.13	0.03	0.06	0.10	-1.00	0.00	0.82
10/29	0.38	0.37	0.34	0.36	0.02	0.39	0.37	-1.00	0.38	0.01
12/03	0.34	8.33	0.33	0.33	0.00	0.34	0.38	-1.00	0.36	0.02
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	0.17	0.17	0.18			0.16	0.17	-1.00	0.17	
STD DEV	0.13	0.13	0.13			0.16	0.16	-1.00	0.36	
MIN	0.00	0.00	0.00			0.00	0.00	-1.00	0.00	
MAX	0.38	0.37	0.34			0.39	0.38	-1.00	0.39	

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DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
Turbidity										
06/05	12.0	20.0	44.0	25.3	16.7	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	7.0	4.0	8.0	6.3	2.1	26.0	19.0	-1.0	22.5	4.9
08/27	3.0	3.0	1.0	2.3	1.2	2.0	3.0	-1.0	2.5	0.7
09/24	3.0	2.0	3.0	2.7	0.6	11.0	9.0	-1.0	10.0	1.4
10/29	3.0	2.0	3.0	2.7	0.6	4.0	4.0	-1.0	4.0	0.0
12/03	5.0	3.0	5.0	4.3	1.2	11.0	7.0	-1.0	9.0	2.8
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	5.5	5.7	10.7			10.8	8.4	-1.0	8.1	
STD DEV	3.6	7.12	16.4			9.4	6.4	-1.0	9.3	
MIN	3.0	2.0	1.0			2.0	3.0	-1.0	1.0	
MAX	12.0	20.0	44.0			11.0	19.0	-1.0	44.0	
VSS										
05/06	7.0	3.0	13.0	7.7	5.0	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	1.0	1.	1.0	1.0	0.0	8.0	5.0	-1.0	6.5	2.1
07/16	0.0	7.0	8.0	5.0	4.4	4.0	8.0	-1.0	6.0	2.8
08/27	0.0	3.0	5.0	2.7	2.5	14.0	7.0	-1.0	10.5	4.9
09/24	1.0	3.0	5.0	3.0	2.0	23.0	10.0	-1.0	16.5	9.2
10/29	4.0	4.0	4.0	4.0	0.0	5.0	5.0	-1.0	5.0	0.0
12/03	3.0	3.0	3.0	3.0	0.0	2.0	2.0	-1.0	2.0	0.0
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	2.3	3.4	5.6			9.3	6.2	-1.0	5.2	
STD DEV	2.6	1.8	3.0			7.9	2.8	-1.0	4.6	
MIN	0.0	1.0	1.0			2.0	2.0	2.0	0.0	
MAX	7.0	7.0	13.0			23.8	10.0	-1.0	23.8	

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DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
Conductivity										
06/05	300.0	280.0	286.7	11.5	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	129.0	125.0	134.0	129.3	4.5	370.0	-1.0	-1.0	370.0	-1.0
08/27	290.0	300.0	290.0	293.3	5.8	390.0	315.0	-1.0	352.5	53.0
09/24	290.0	290.0	295.0	291.7	2.0	440.0	-1.0	-1.0	440.0	-1.0
10/29	-1.8	310.0	305.0	397.5	3.5	300.0	385.0	-1.0	302.5	3.5
12/03	328.0	309.0	318.0	315.7	10.7	300.0	307.0	-1.0	308.5	4.9
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	267.4	269.0	269.0			360.0	309.0	-1.0	291.7	
STD DEV	78.0	71.5	67.0			60.4	5.3	-1.0	71.0	
MIN	129.0	125.0	134.0			300.0	305.0	-1.0	125.0	
MAX	328.0	310.0	318.0			440.0	315.0	-1.0	440.0	
P-ALK										
06/05	-1.0	0.0	-1.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	0.0	10.0	10.0	6.7	5.8	0.0	0.0	-1.0	0.0	0.0
07/16	18.0	16.0	16.0	16.7	1.2	0.0	0.0	-1.0	0.0	0.0
08/27	10.0	10.0	10.0	10.0	0.0	0.0	0.0	-1.0	0.0	0.0
09/24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0
10/29	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	7.0	6.0	7.2			0.0	0.0	-1.0	4.0	
STD DEV	8.7	6.0	7.0			0.0	0.0	-1.0	6.2	
MIN	0.0	0.0	0.0			0.0	0.0	-1.0	0.0	
MAX	18.0	16.0	16.0			0.0	0.0	-1.0	18.0	

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DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
PH										
06/05	7.5	7.7	7.7	7.6	0.1	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	8.3	8.4	8.5	8.4	8.1	7.6	-1.0	-1.0	7.6	-1.0
08/27	7.9	8.4	8.4	8.2	0.3	6.8	7.3	-1.0	7.1	0.4
09/24	7.5	7.5	7.8	7.6	0.2	7.2	-1.0	-1.0	7.2	-1.0
10/29	7.8	7.8	-1.0	7.8	0.0	7.6	7.5	-1.0	7.6	0.0
12/03	8.1	8.2	8.3	8.2	0.1	8.2	8.2	-1.0	8.2	0.0
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	7.9	8.0	8.1			7.5	7.7	-1.0	7.9	
STD DEV	0.3	0.4	0.4			0.5	0.5	-1.0	0.4	
MIN	7.5	7.5	7.7			6.8	7.3	-1.0	6.8	
MAX	8.3	8.4	8.5			8.2	8.2	-1.0	8.5	
SECCHI										
06/05	24.0	12.0	7.0	14.3	8.7	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	36.0	36.0	24.0	32.0	6.0	-1.0	-1.0	-1.0	-1.0	-1.0
07/16	36.0	30.0	22.0	29.3	7.0	-1.0	-1.0	-1.0	-1.0	-1.0
08/27	45.0	42.0	32.0	39.7	6.8	-1.0	-1.0	-1.0	-1.0	-1.0
09/24	24.0	25.0	11.0	20.0	7.8	-1.0	-1.0	-1.0	-1.0	-1.0
10/29	-1.0	12.0	10.0	11.0	1.4	-1.0	-1.0	-1.0	-1.0	-1.0
12/03	22.0	21.0	20.0	21.0	1.0	-1.0	-1.0	-1.0	-1.0	-1.0
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	31.2	25.4	18.0			-1.0	-1.0	-1.0	24.6	
STD DEV	9.2	11.5	8.0			-1.0	-1.0	-1.0	10.0	
MIN	22.0	12.0	7.0			-1.0	-1.0	-1.0	7.0	
MAX	45.0	42.0	32.0			-1.0	-1.0	-1.0	7.0	

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DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
COD										
06/05	21.0	22.0	22.0	21.7	0.6	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	20.0	19.0	22.0	20.3	1.5	55.0	18.0	-1.0	36.5	26.2
07/16	20.0	20.0	23.0	21.0	1.7	22.0	19.0	-1.0	-20.5	2.1
08/27	22.0	19.0	28.0	23.0	4.6	26.0	20.0	-1.0	23.0	4.2
10/29	16.0	18.0	18.0	17.3	1.2	16.0	19.0	-1.0	17.5	2.1
12/03	16.0	18.0	15.0	16.3	1.5	16.0	15.0	-1.0	15.5	0.7
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	19.9	22.7	41.7			29.8	19.7	-1.0	26.0	
STD DEV	3.0	9.1	54.1			16.1	4.0	-1.0	26.1	
MIN	16.0	18.0	15.0			16.0	15.0	-1.0	15.0	
MAX	24.0	43.0	164.0			55.0	27.0	-1.0	164.0	
T-ALK										
06/05	0.0	-1.0	-1.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	144.0	144.0	130.0	139.3	8.1	200.0	170.0	-1.0	185.0	21.2
07/16	146.0	144.0	128.0	136.7	14.5	198.0	152.0	-1.0	175.0	32.5
08/27	120.0	120.0	120.0	120.0	0.0	190.0	140.0	-1.0	165.0	35.4
09/24	114.0	122.0	118.0	118.0	4.0	200.0	122.0	-1.0	161.0	55.2
10/29	-1.0	140.0	130.0	135.0	7.1	125.0	100.0	-1.0	112.5	17.7
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	104.8	134.0	123.6			182.6	136.8	-1.0	136.4	
STD DEV	60.3	12.0	5.9			32.5	27.0	-1.0	40.3	
MIN	0.0	120.0	118.0			125.0	100.0	-1.0	0.0	
MAX	146.0	144.0	130.0			200.0	170.0	-1.0	200.0	

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DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV.	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
D.O.										
06/05	5.3	6.4	5.6	5.4	0.2	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	8.2	8.4	10.2	8.9	1.1	0.1	-1.0	-1.0	0.1	-1.0
07/16	8.1	7.9	8.4	8.1	8.3	0.0	-1.0	8.0	4.0	5.7
08/27	9.7	10.7	10.6	10.3	0.6	0.0	0.4	-1.0	0.2	0.3
09/24	5.8	8.7	10.7	8.4	2.5	0.3	-1.0	-1.0	0.3	-1.0
10/29	9.5	9.9	10.4	9.9	0.5	8.8	10.2	-1.0	9.5	1.0
12/03	12.3	13.2	13.9	13.1	0.8	12.7	13.0	-1.0	12.9	0.2
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	8.4	9.2	10.0			3.7	7.9	8.0	7.0	
STD DEV	2.4	2.4	2.5			5.6	6.6	-1.0	4.1	
MIN	5.3	5.4	5.6			0.0	0.4	8.0	0.0	
MAX	12.3	13.2	13.0			12.7	13.0	8.0	13.0	
CHLB										
06/05	0.4	0.4	1.3	0.7	0.5	-1.0	-1.0	-1.0	-1.0	-1.0
06/25	4.3	1.5	10.7	5.5	4.7	-1.0	-1.0	-1.0	-1.0	-1.0
07/16	2.1	4.8	3.1	3.3	1.4	-1.0	-1.0	-1.0	-1.0	-1.0
08/27	30.0	5.3	6.7	5.0	1.9	-1.0	-1.0	-1.0	-1.0	-1.0
09/24	1.4	4.4	5.3	3.7	2.0	-1.0	-1.0	-1.0	-1.0	-1.0
10/29	1.2	1.1	0.7	1.0	0.3	-1.0	-1.0	-1.0	-1.0	-1.0
12/03	1.5	1.0	0.0	0.8	0.8	-1.0	-1.0	-1.0	-1.0	-1.0
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	2.0	2.6	4.0			-1.0	-1.0	-1.0	2.9	
STD DEV	1.3	2.1	3.8			-1.0	-1.0	-1.0	1.6	
MIN	0.4	0.4	0.0			-1.0	-1.0	-1.0	0.0	
MAX	4.3	5.3	10.7			-1.0	-1.0	-1.0	10.7	

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DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
T-PHOS										
06/05	0.10	0.13	0.19	0.14	0.84	-1.00	-1.00	-1.00	-1.00	-1.00
06/25	0.05	0.08	0.11	0.08	0.03	0.37	0.11	-1.00	0.24	0.18
07/16	0.05	0.06	0.11	0.07	0.03	0.43	0.19	-1.00	0.31	0.17
08/27	0.03	0.04	0.07	0.84	0.81	0.66	0.13	-1.00	0.39	0.37
09/24	0.06	0.08	0.10	0.08	0.02	0.56	0.10	-1.00	0.33	0.32
10/29	0.09	0.08	0.10	0.09	0.01	0.11	0.11	-1.00	0.11	0.00
12/03	0.04	0.04	0.04	0.04	0.00	0.04	-1.00	0.04	0.00	
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	0.06	0.07	0.10			0.36	0.11	-1.00	0.13	
STD DEV	0.02	0.03	0.04			0.24	0.04	-1.00	0.38	
MIN	0.03	0.04	0.04			0.04	0.94	-1.00	0.03	
MAX	0.10	0.13	0.19			0.66	0.19	-1.00	0.66	
D-PHOS										
06/05	0.04	0.05	0.07	0.06	0.01	-1.00	-1.00	-1.00	-1.00	-1.00
06/25	0.01	0.02	0.01	0.01	0.00	0.14	0.03	-1.00	0.88	0.87
07/16	0.04	0.04	0.04	0.04	0.00	0.16	0.05	-1.00	0.10	0.07
08/27	0.03	0.20	0.03	0.02	0.00	0.05	0.05	-1.00	0.15	0.17
09/24	0.01	0.04	0.03	0.02	0.01	0.27	0.03	-1.00	0.04	0.00
10/29	0.05	0.04	0.04	0.04	0.00	0.04	0.04	-1.00	0.04	0.00
12/03	0.02	0.02	0.01	0.01	0.00	0.01	-1.00	-1.00	0.01	0.00
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	0.02	0.03	0.03			0.12	0.04	-1.00	0.04	
STD DEV	0.01	0.01	0.02			0.09	0.02	-1.00	0.23	
MIN	0.01	0.02	0.01			0.01	0.01	-1.00	0.01	
MAX	0.05	0.05	0.07			0.27	0.09	-1.00	0.27	

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DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
CHLORIDE										
06/05	9.10	9.10	11.00	9.73	1.09	-1.00	-1.00	-1.00	-1.00	-1.00
06/25	13.00	9.80	9.80	10.86	1.84	13.00	9.80	-1.00	11.40	2.26
07/16	11.00	10.00	9.90	18.30	0.60	9.60	9.90	-1.00	9.75	0.21
08/27	12.00	9.40	9.70	10.36	1.42	11.00	9.50	-1.00	10.25	1.06
09/24	9.10	8.00	8.20	8.43	0.48	11.00	8.30	-1.00	9.65	8.21
10/29	8.30	8.30	8.50	8.36	0.11	8.69	8.30	-1.00	8.45	0.21
12/03	8.20	8.60	8.20	8.33	0.23	8.80	8.40	-1.00	8.60	0.28
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	10.10	9.02	9.32			10.33	9.03	-1.00	9.55	
STD DEV	1.90	0.74	1.05			1.66	0.77	-1.00	1.16	
MIN	8.20	8.00	8.20			8.60	8.30	-1.00	8.00	
MAX	13.00	10.00	11.00	13.000	9.900	-1.00	13.00			
CHLA UNC										
06/05	12.10	12.90	12.70	12.56	0.41	12.10	12.90	-1.00	12.50	0.56
06/25	21.80	8.10	-1.00	14.95	9.68	21.00	8.10	41.50	23.83	16.84
07/16	18.70	28.20	-1.00	23.45	6.71	18.70	28.20	19.40	22.10	5.29
08/27	11.60	15.30	-1.00	13.45	2.61	11.60	15.30	26.00	17.63	7.47
09/24	17.30	36.40	-1.00	026.85	13.50	17.30	36.40	35.90	29.86	18.88
10/29	10.70	8.00	-1.00	9.35	1.00	10.70	8.00	8.60	9.10	1.41
12/03	17.10	17.00	-1.00	17.50	0.56	17.10	17.90	13.70	16.23	2.23
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	15.61	18.11	12.70			15.61	18.11	24.20	18.00	
STD DEV	1.10	10.59	-1.00			4.19	10.59	12.80	2.99	
MIN	10.70	8.00	12.70			10.70	8.00	8.60	8.00	
MAX	21.80	36.40	12.70			21.80	36.40	41.60	41.60	

1980 AMBIENT LAKE DATA, PITTSFIELD CITY LAKE, PIKE COUNTY, ILLINOIS

DATE	SITE 1	SITE 2	SITE 3	MEAN	STD DEV	SITE 1	SITE 2	SITE 3	MEAN	STD DEV
CHLA COR										
06/05	9.9	10.7	10.6	10.4	0.4	9.9	10.7	-1.0	10.3	0.6
06/25	22.0	8.2	-1.0	15.1	9.8	22.0	8.2	39.2	23.1	15.5
07/16	17.0	27.8	-1.0	22.9	7.0	17.9	27.8	19.0	21.6	5.4
08/27	9.9	11.4	-1.0	10.7	1.1	9.9	11.4	21.7	14.3	6.5
09/24	16.7	36.9	-1.0	26.8	14.3	16.7	36.9	31.9	28.5	10.5
10/29	10.0	7.0	-1.0	8.5	2.1	10.0	7.0	6.9	8.0	1.8
12/03	17.0	22.3	-1.0	19.7	3.7	17.0	22.3	15.6	18.3	3.5
SUMMARY STATISTICS			SITES-TOP				SITES-BOTTOM		LAKE	
MEAN	14.8	17.8	10.6			14.8	17.8	22.4	17.2	
STD DEV	4.8	11.4	-1.0			4.8	11.4	11.6	0.1	
MIN	9.0	7.0	10.6			9.9	7.0	6.9	6.9	
MAX	22.0	36.0	10.6			22.0	36.9	30.2	39.2	

TED:dks:sp/2984c, 1-118

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S
SA    WATER QUALITY DATA BLUE CREEK                                                  WATER QUALITY DATA BLUE CREEK
SA ID DATE TIME   TSS  IVS   TKN  COD   NH3  N32   PTL  DSP    KTL   FET  BOD TEM    PH  DOXY  CON  TUD
ST.A800502 1145     7    3
ST.A800505 1130    14    7
ST.A800507 0920    12    5   1.4   26   0.0  0.0  0.09         6.4   130       16
ST.A800507 0925    14    9
ST.A800509 1030    14    6                                                     18
ST.A800512 1120    12    4                                                     18
ST.A800514 0920    13    7   1.5   21   0.1  0.0  0.08         4.9   270   10
ST.A800514 0955                                                                18   8.9  10.7  292
ST.A800514 1010    17    3
ST.A800516 1430    12    4                                                     16
ST.A800519 1445     9    4                                                     18
ST.A800521 1000   170   21
ST.A800521 1000    17    9   1.5   30     0    0  0.12          13   130   10  19   8.3  18.0  355
ST.A800523 1000     8    4                                                     19
ST.A800526 0900    18   10                                                     23
ST.A800528 0900    13  0.0
ST.A900528 0900    11    5   1.0   25   0.0  0.0  0.06         4.4    60    6  23   7.7   9.0  285
ST.A900530 1430    24    3                                                     25
ST.A800602 1400    20    9                                                     23
ST.A900604 1330    14    2
ST.A800605 0800    12    0   1.1   19   0.2  0.1  0.12         4.7   740    4  21   7.5   4.7  285
ST.A800606 1055    16    3                                                     25
ST.A800609 1400    23    3                                                     24
ST.A800611 0915    11    3
ST.A800611 0915    15    5   1.2   20     0    0               4.8   460    8  22   8.4  13.1  285
ST.A800613 1010     9    3                                                     22
ST.A800616 1050    11    1
ST.A800618 0730     9    1   1.0   17     0    0  0.05         4.8   180    4  23   8.5   9.7  290
ST.A800620 1050     9    1                                                     24
ST.A800623 1005     5    3                                                     25
ST.A800625 0700     5    4   0.5   18     0    0  0.05         3.7   240    4  24   7.5   7.8  308
ST.A800627 1355    13    4                                                     30
ST.A800630 1135     9    8                                                     29
ST.A800702 0825     8    2   0.6   25     0    0  0.06        4.69   200    4  27   8.4   9.8  300
ST.A800704 1040    17    4                                                     28
ST.A800707 1150     3    2                                                     30
ST.A900709 0830     4    1   1.1   20     0    0  0.06         5.9   390    3  29         7.2  325
ST.A800711 1105     7  0.0                                                     32
ST.A800714 1230    10    1                                                     32
ST.A800716 0910    11    3   0.6   19     0    0  0.05         4.6   210    4  30         7.8  275
ST.A800718 1445    15  0.0                                                     31
ST.A800721 1005    12    2                                                     30
ST.A800723 0950    14    1   0.6   17     0    0  0.05         5.5   270    3  29   8.9   7.3  290
ST.A800725 1115     9    3                                                     28
ST.A800728 1405     9    2                                                     29
ST.A800730 0945    10    1   0.8   20     0    0  0.04         0.6   200    4  27         9.1  320
ST.A800804 1015     8    4                                                     27
ST.A800806 0945    12    6   0.6   20     0    0  0.05         5.0   280    3  27   7.7   6.3  280
ST.A800808 1010     9    1                                                     28
ST.A800811 0945     4  0.0                                                     28
ST.A800813 0925     5    1   0.8   19     0    0  0.04         5.1   200    4  27   9.7   7.9  290
ST.A800815 1415    10    4                                                     28
ST.A900818 1030     7    3                                                     28
ST.A800820 1130     6    2   0.6   18             0.05         4.3   270    3  30   8.4  12.7  265
ST.A800822 1610     7    2                                                     31
ST.A900825 0915     2    0                                                     27
ST.A800827 0850     1    0   0.6   17             0.03         4.2   120    3  27         8.9  250
ST A800901 1915    INSUFFICIENT SAMPLE                                         27
ST.A800903 0945     6    2   0.9   15   0.1       0.04         4.1   230    3  26         5.6  270
ST.A800905 1520    11    3                                                     25
ST.A800908 0940     8    3                                                     25
ST.A800910 0910    12    3   0.8   18             0.05         4.4   220    4  25   6.7   7.9  220
ST.A800912 1400     7    0                                                     26
ST.A800915 1350    12    2                                                     26
ST.A800917 0920    16    5   0.9   24   0.3  0.1  0.05         5.2  1100    2  23   6.6   5.2  265
ST.A800919 1435     9    7                                                     24
ST.A800922 1010    14    5                                                     25
ST.A800924 1315    16    4   0.9   20   0.1  0.2  0.07         5.5   330    7  24   7.5  10.2  305
ST.A800926 1550    10    0                                                     23
ST.A800929 1330    12    6                                                     21
ST.8800430 1500   40    9
ST.8800502 1210   31    7
ST.8800503 1310  110   12
ST.8800504 1355   41   11
ST.8800505 1115   65   13
ST.8800506 1010   70   13
ST.8800507 0905   26   12                                                    18
ST.8800507 0910   75   10  1.8   26  0.5  1.3 0.22        5.1 1200          16
ST.8800508 1345   75    9
ST.8800509 1015   22    4                                                    19
ST.8800510 0820  140   15                                                    16
ST.8800511 0920   65   10                                                    15
ST.8800512 1130   55    8                                                    16
ST.8800513 1425  430   38                                                    17
ST.8800514 1055  230   22                                                    20
ST.8800515 1420  140   13  2.5   36  0.4  0.5 0.41        6.1 4100       9  17  7.8  7.5 345
ST.8800516 1420  130   21                                                    22
ST.8800517 1425  270  100                                                    17
ST.8800518 1135  130   31                                                    18
ST.8800519 1500  190   23                                                    16
ST.8800520 1105   75    8                                                    19
ST.8800521 1030  120   15                                                    19
ST.8800522 0900  220   27  2.2   28  0.5  1.6 0.32        5   3000       4  18  7.5  4.7 490
ST.8800523 1000  130   18                                                    20
ST.8800524 0900  200   24                                                    18
ST.8800525 0900  210   21                                                    18
ST.8800526 0900  230   26                                                    27
ST.8800527 0900  290   26                                                    28
ST.8800528 0915  100   14                                                    28
ST.8800528 0920  100   19  2.4   29  0.4  0.9  0.3        4.5 1400       9  23  6.8  4.0 510
ST.8800529 1500  140   16
ST.8800530 1420  300   14                                                    30
ST.8800531 0820   60    9                                                    29
ST.8800601 1300 4100  580                                                    22
ST.8800602 1410  230   26                                                    19
ST.8800603 1435  390   36                                                    22
ST.8800604 1340 2080  150                                                    27
ST.8800605 0815  200   17
ST.8800606 1105  110   10  1.8   30  0.2  0.4 0.36        5.5 7830       4  21  7.3  5.5 295
ST.8800609 1410  110   12                                                    26
ST.8800610 1005   44    6                                                    26
ST.8800611 0925   85   14                                                    22
ST.8800611 0925   80    8
ST.8800611 1435  200   14  1.0   24  0.1  0.2             4.9 2700       6  24  7.4  9.4 305
ST.8800613 1020  110   11
ST.8800614 1440   90   10                                                    22
ST.8800615 1020   85   11
ST.8800616 1100   90   10
ST.8800617 0950   85   12
ST.8800618 1000   46    8                                                    20
ST.8800619 1755   28    8  0.7   24    0    0 0.15        4.9  950       6  23  8.0  5.3 325
ST.8800620 1040   99    0                                                    26
ST.8800621 0900   50    0                                                    22
ST.8800622 1835   60    3                                                    21
ST.8800623 1015   93   12                                                    28
ST.8800624 1015   95    3                                                    26
ST.8800625 0750   25   13                                                    23
ST.8800626 1000   95   14  1.3   23  0.2  0.3 0.24        4.7 1370       4  24  7.3  5.0 360
ST.8800627 1410  120   15                                                    26
ST.8800628 1250   70    5                                                    34
ST.8800629 0850   60   10                                                    35
ST.8800630 1150   49   10                                                    21
ST.8800701 0940  110   11                                                    29
ST.8800702 0850  120   18                                                    28
ST.8800703 1015   60   10  0.7   25  0.2    0 0.26       4.95 3400       3  29  7.5  2.2 330
ST.8800704 1055   90    8                                                    23
ST.8800705 1025  120   15                                                    29
ST.8800706 1313  100   19                                                    29
ST.8800707 1200  110   23                                                    27
ST.8800708 0915   75   17                                                    33
ST.8800709 0850   85    9                                                    29
ST.8800710 0915  130   11  1.4   25    0    0 0.21        5.3 3400       4  29       6.8 295
ST.8800711 1115   75   13                                                    30
ST.8800712 1425   60    9                                                    32
ST.8800713 1605  160   14                                                    36
ST.8800714 1240  100   14                                                    36
ST.8800715 1535  210   21                                                    37
ST.8800716 0930  170   23                                                    37
ST.8800717 1010   38    1  0.9   31    0    0 0.27        5.161700       6  30       6.5 295
ST.8800718 1455  160    3                                                    30
ST.8800719 1305   87   10                                                    34
ST.8800720 1505   90   10                                                    35
ST.8800721 1015   80    8                                                    36
ST.8800722 1455  120   14                                                    31
ST.8800723 1030   29    8                                                    31
ST.8800724 1030   65    9  0.6   19    0    0 0.11        5.6  690       2  28 11.3  7.1 340
ST.8800725 1125   85   11                                                    28
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ST.B800725 1125   85   11                                                  30
ST.B800726 1240   55   12                                                  28
ST.B800727 1730   46    9                                                  26
ST.B800728 1415   46    7                                                  23
ST.B800729 1030   46    6                                                  28
ST.B800730 1005   49    5  0.9   20    0     0 0.11     4.3 1200   3     26        7.1 315
ST.B800801 1110   68   11                                                  28
ST.B800802 1505   50   10                                                  26
ST.B800803 1230   35   10                                                  30
ST.B800804 1025   70   11                                                  29
ST.B800805 1400   80   14                                                  31
ST.B800806 1005  120   17  1.6   34  0.1   0.1 0.32     6.5 5200   7     27  7.7  5.1 285
ST.B800807 1830   37   15                                                  34
ST.B800808 1020   48    9                                                  30
ST.B800809 1350   90    5                                                  36
ST.B800809 1400   52   11
ST.B800810 1005   49    5                                                  31
ST.B800811 1000   64   10                                                  30
ST.B800812 1040   39    5                                                  27
ST.B800813 0945   60   11  1.3   26    0     0 0.14     5.5 2000   4     26        9.5 290
ST.B800814 1630   75    8                                                  30
ST.B800815 1405  470   65                                                  25
ST.B800816 1055  810  120                                                  21
ST.B800817 1115   80    9                                                  30
ST.B800818 1020  100   15                                                  27
ST.B800819 1220   41    7                                                  32
ST.B800820 1055   49    6  1.0   24             0.18     4.6 1600   4     31  8.2  8.8 300
ST.B800821 1420   75    7                                                  30
ST.B800822 1600   65   11                                                  30
ST.B800823 1400   55    5                                                  30
ST.B800824 1010   46    0                                                  27
ST.B800825 0925   50    0                                                  26
ST.B800826 0920   60    6                                                  27
ST.B800827 0910   60    2  1.1   24             0.17     4.5 1700   4     28        6.6 285
ST.B800828 0845   69   11                                                  28
ST.B800829 1025   67   10                                                  28
ST.B800830 0830   87   12                                                  28
ST.B800831 1450   36   15                                                  30
ST.B800901 1925   77   13                                                  27
ST.B800902 1015   24    7                                                  27
ST.B800903 0910   60    8  1.2   20             0.13     4.3 1400   5     23        5.1 300
ST.B800904 1415  120   14                                                  26
ST.B800905 1535  390   36                                                  26
ST.B800906 1015   55    8                                                  27
ST.B800907 1010   80    9                                                  26
ST.B800908 0950   43    9                                                  26
ST.B800909 1030  210   18                                                  27
ST.B800910 0935   55    9  1.6   23  0.4        0.20     4.9 1600   5     24  7.5  2.8 265
ST.B800911 1030   55    6                                                  27
ST.B800912 1410   90    7                                                  27
ST.B800913 0920   37    4                                                  28
ST.B800914 1940   80    7                                                  27
ST.B800915 1400   63    5                                                  26
ST.B800916 0920   75    8                                                  24
ST.B800917 0950   69    9  1.2   26  0.1   0.1 0.22     6.0 2100   7     21        6.2 260
ST.B800918 1455  130   28                                                  26
ST.B800919 1445  160   26                                                  25
ST.B800920 0910   57   10                                                  23
ST.B800921 1040   47   13                                                  25
ST.B800922 1020   66   12                                                  27
ST.B800923 1520   40   10                                                  21
ST.B800924 1335   76   13  1.3   25  0.1   0.1 0.19     5.5 1200   7     22       11.2 300
ST.B800925 1025   53    4                                                  22
ST.B800926 1600   64    9                                                  24
ST.B800927 1130   42    7                                                  18
ST.B800928 1305   45    3                                                  20
ST.B800929 1340   46    9                                                  22
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ST.C800324 0930  730   95
ST.C800330 1030 2270  210
ST.C800415 1600 1070   90
ST.C800415 1610 1130   85
ST.C800430 1430   12    0
ST.C800502 1222   15    4
ST.C800503 1320   17    2
ST.C800504 1410   17    4
ST.C800505 1100   23    2
ST.C800506 0955   28    3                                                 16
ST.C800507 0840   27    6  1.1   15  0.1  2.4  .12        2.6  640    6  14
ST.C800507 0850   26    4
ST.C800508 1330   16    5                                                 15
ST.C800509 1000   14    3                                                 11
ST.C800510 0810   26    5                                                 13
ST.C800511 0900   26    7                                                 13
ST.C800512 1130 8130  550
ST.C800512 1145   28    7                                                 15
ST.C800512 2120  220   35
ST.C800513 1050 6480  430
ST.C800513 1410  500   60                                                 18
ST.C800513 1445 3840  360
ST.C800514 1107  130   13
ST.C800514 1107   75    8  2.0   20  0.5  2.6  .29        4.6 1800    5  13  7.4  7.4 575
ST.C800515 1435  170   13                                                 18
ST.C800516 1350 5540  230                                                 13
ST.C800517 1115 4200  170
ST.C800517 1135 1740   90
ST.C800517 1200 1160   90
ST.C800517 1205 3630  140
ST.C800517 1225 4720  270
ST.C800517 1305 2600  230
ST.C800517 1500  280   30
ST.C800518 1125   70    4                                                 14
ST.C800519 1400   65    5                                                 14
ST.C800520 1125                                                           15
ST.C800521 1110                                                           15  7.4  9.4 565
ST.C800522 0900   70    9                                                 14
ST.C800523 1000   75   10
ST.C800524 0900  100   12                                                 15
ST.C800525 0900   65   10                                                 23
ST.C800526 0900   70   10                                                 23
ST.C800527 0900   70    4                                                 23
ST.C800528 0930   95   11
ST.C800528 0940  100   14  1.3   13  0.1  3.3  .22        2.6 1700    5  22  6.5  8.0 620
ST.C800529 1520   65    6                                                 24
ST.C800530 0810  200   17
ST.C800530 0910 2310  110
ST.C800530 1410  110   11                                                 26
ST.C800531 0805   80    6                                                 19
ST.C800531 2245 6240  400
ST.C800601 073576000 2250
ST.C800601 074537000 1720
ST.C800601 080053000 2150
ST.C800601 085031000 1250
ST.C800601 090530000 1400
ST.C800601 094526100 1550
ST.C800601 102518200 1150
ST.C800601 113012450  750
ST.C800601 1400 4675  350
ST.C800602 1430  155   16                                                 18
ST.C800603 0015 8150  450
ST.C800503 012518050  900
ST.C800603 021011080  780
ST.C800603 030010030  750
ST.C800603 1450  320   33                                                 24
ST.C800604 0930 2090  170
ST.C800604 102524300 1250
ST.C800604 105515000  950
ST.C800604 114512700  650
ST.C800605 0830  140   12  1.5   23  0.3  4.3  .42        4.1 4900    6  17  7.3  9.9 510
ST.C800606 1130  100    4                                                 20
ST.C800609 1425   55    3                                                 20
ST.C800610 1015  100    5                                                 18
ST.C800611 1000   95   11
ST.C800611 1000   90    6  0.6   11  0.1  4.4             2.0 2500    3  16  8.2  9.9 520
ST.C800612 1445   30    1                                                 20
ST.C800613 1005                                                           22       4.8 385
ST.C800613 1030   38    4                                                 18
ST.C800614 1455   65    5
ST.C800615 1030   50    4
ST.C800616 1115   43    3
ST.C800617 1135   36    2                                                 18
ST.C800618 0800   95    7  0.7   11  0.1  3.9  .18        1.8 1400    4  17  7.2  8.2 610
ST.C800619 1805   19    3                                                 21
ST.C800620 1115   35    3                                                 21
ST.C800621 0915   46    2                                                 17
ST.C800622 1845   34    8                                                 23
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ST.C800623 1030    45     5                                                       24
ST.C800624 1000    91     3                                                       20
ST.C800625 0830    75     8   0.7    15  0.1  3.0  .21         3.5 1240        3  20  6.8   8.1 560
ST.C800626 1030    38     4                                                       21
ST.C800627 1420    44     7                                                       28
ST.C800628 1300    37     5                                                       28
ST.C800629 0900    45     9
ST.C800630 1200    38     6                                                       22
ST.C800701 0950    50     8                                                       23
ST.C800702 0930    49     6   0.6    13  0.1  2.4  .21        1.95 1400        3  24  7.7   5.8 565
ST.C800703 0905   120     8                                                       19
ST.C800704 1105    95     9                                                       24
ST.C800705 1035   110    19                                                       25
ST.C800706 1325   110    20                                                       24
ST.C800707 1210    60    14                                                       27
ST.C800708 0905    49    14                                                       26
ST.C800709 0920    80     9   1.2    17  0.2  2.4  .29         4.4 2900        3  26        5.7 525
ST.C800710 1020    49     4                                                       26
ST.C800711 1135    40     1                                                       27
ST.C800712 1435    32     5                                                       31
ST.C800713 1620    28     7                                                       30
ST.C800714 1540    29     4                                                       31
ST.C800715 1545    22     1                                                       30
ST.C800716 0945    40     4   0.7    16    0  1.2  .20         5.111300        3  27        6.0 550
ST.C800717 1020    26     0                                                       24
ST.C800718 1510    28     1                                                       27
ST.C800719 1315    26     4                                                       29
ST.C800720 1515    10     1                                                       30
ST.C800721 1025    55    13                                                       27
ST.C800722 1455    41     3                                                       27
ST.C800723 1055    43     8   1.0    25    0    0  .24         6.7 1290        4  22  9.6   9.1 560
ST.C800724 1045    25     7                                                       25
ST.C800725 1135    28     6                                                       26
ST.C800726 1250    38    11                                                       22
ST.C800727 1740    27     5                                                       21
ST.C800728 1430    21     5
ST.C800729 1045    22     4                                                       22
ST.C800730 1020    30     7   0.9    19  0.2    0  0.2         3.1 1700        4  22        7.2 625
ST.C800801 1120    55    22                                                       24
ST.C800802 1515    50    23                                                       26
ST.C800803 1240    45    15                                                       24
ST.C800804 1035    75    19                                                       22
ST.C800804 202012670  9130
ST.C800805 1415   340    50                                                       25
ST.C800806 1050   700   110   5.3   121  1.1  1.5  2.1         21. 39000      16  23  7.3   5.3 290
ST.C800807 1845   122    15                                                       28
ST.C800808 1030   104    11                                                       25
ST.C800810 1015    83     9                                                       26
ST.C800811 1010    78    14                                                       24
ST.C800812 1050    97    32                                                       23
ST.C800813 1005   150    26   2.6    68  0.2    0  .38          10 5700        6  22        4.8 385
ST.C800814 1535   130    23                                                       25
ST.C800815 075513000    530
ST.C800815 0810 6900    360
ST.C800815 0830 4300    230
ST.C800815 0850 2200    130
ST.C800815 0905 1500     80
ST.C800815 0925 4000    210
ST.C800815 0945 3000    190
ST.C800815 1000 3000    200
ST.C800815 1025 3500    270
ST.C800815 1100 2900    160
ST.C800815 1330 2000    240
ST.C800815 1435 1700    180
ST.C800816 0555 3500    210
ST.C800816 0625 4900    320
ST.C800816 0650 5500    290
ST.C800816 0700 4200    240
ST.C800816 0750 3200    200
ST.C800816 0815 3900    300
ST.C800816 0825 4300    340
ST.C800816 0908 2700    210
ST.C800816 0925 2000    160
ST.C800816 1105 1500    130
ST.C800816 1215 1300    100
ST.C800816 1805 8500    360
ST.C800816 1820 5400    230
ST.C800816 1837 3500    190
ST.C800816 1850 4600    210
ST.C800816 1905 4100    210
ST.C800816 1920 4900    360
ST.C800816 1950 4200    210
ST.C800816 2020 2900    190
ST.C800816 2120 2200    210
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ST.C800816 2230 2200   140
ST.C800817 1125  430    55                                                24
ST.C800818 0800  210    26                                                24
ST.C800819 1235  210    14                                                26
ST.C800820 1205  150    11  2.4   38  0.9  0.8  0.48      10.5 4400   12  26  5.7  5.5 480
ST.C800821 1450  510    40                                                25
ST.C800822 1625                                                           25
ST.C800823 1410   70     8                                                25
ST.C800824 1025   95     5                                                21
ST.C800824 1025   95     5
ST.C800825 0935   75     6                                                20
ST.C800826 0930   47     0                                                20
ST.C800827 0925   45     9  1.3   26  0.1  0.9  0.24       7.9 1600    6  21       4.5 455
ST.C800828 0900   28     7                                                22
ST.C800829 1035   27     5                                                22
ST.C800830 0850   17     6                                                22
ST.C800831 1530   73    15                                                22
ST.C800901 1935   31     7                                                23
ST.C800902 1035  360    52                                                23
ST.C800903 0930  120    22  3.0   56  0.2  1.0  0.71       8.4 3400   18  21       6.6 420
ST.C800904 0740 4240   400
ST.C800904 0800 6470   350
ST.C800904 0820 2050   140
ST.C800904 0850  DISCARDED BEFORE ANALYSTS
ST.C800905 0850 6100   300
ST.C800905 0905 6260   340
ST.C800905 0915 3790   180
ST.C800905 0925 3630   170
ST.C800905 0935 2580   210
ST.C800905 0945 5320   300
ST.C800905 1000 3690   240
ST.C800905 1015 5030   310
ST.C800905 1030 2760   210
ST.C800905 1045 2450   210
ST.C800905 1100 3460   300
ST.C800905 1115 1780   140
ST.C800905 1130 4040   260
ST.C800905 1145 4170   310
ST.C800905 1215 3450   260
ST.C800905 1230 2790   230
ST.C800905 1245 2370   200
ST.C800905 1300 2470   230
ST.C800905 1315 1680   100
ST.C800905 1330 1990   160
ST.C800905 1345 1260   110
ST.C800906 1025  160    20                                                21
ST.C800907 1020  640    70                                                21
ST.C800908 1000  200    26                                                21
ST.C800909 1040   90    12                                                24
ST.C800910 1000   85    15  3.8   32  2.1  0.6  0.40       8.9 3000   15  20  6.5  6.0 420
ST.C800911 1045   92     9                                                23
ST.C800912 1430   42     7                                                24
ST.C800913 0930   61     7                                                23
ST.C800915 1430   36     5                                                23
ST.C800916 0930  230    25                                                20
ST.C800916 1835 4340   250
ST.C800916 1845 3860   160
ST.C800916 1855 5430   170
ST.C800916 1910   59     3
ST.C800916 1930 3890   200
ST.C800916 1945 2350   120
ST.C800916 2000 3670   170
ST.C800916 2035 1480   150
ST.C800916 2100 2490   170
ST.C800916 2130 1650   120
ST.C800916 2200 2530   160
ST.C800917 1020  210    22  2.9   50  0.8  1.4   1.1       12. 9000   13  15       7.9 315
ST.C800918 1505  130    27                                                19
ST.C800919 1455   33     5                                                20
ST.C800920 0925   33     6                                                19
ST.C800921 1055   27     8                                                22
ST.C800922 1115   25     6                                                23
ST.C800923 1530   17     1                                                17
ST.C800924 1350   19     4  1.2   22  0.1  0.9  0.17       7.4  700    6  16      12.0 610
ST.C800925 1035   17     0                                                17
ST.C800926 1610   10     1                                                14
ST.C800927 1140   67     3                                                13
ST.C800928 1315   10     2                                                15
ST.C800929 1350    6     1                                                13
ST.C800930 1340    4     0                                                16
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